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Contents

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Dr. Brian Nolan
Editor
ITB Journal
Institute of Technology Blanchardstown
Blanchardstown Road North
Blanchardstown
Dublin 15

Editorial

I am delighted to introduce the 11th issue of the ITB Journal, the academic journal of the Institute of Technology Blanchardstown. The aim and purpose of the journal is to provide a forum whereby the members of ITB, visitors and guest contributors from other third level colleges can publish an article on their research in a multidisciplinary journal and thereby share their work with the broader community at ITB and other academic institutions.

The first paper in this issue of the ITB Journal is by Gareth Curran (School of Informatics and Engineering, ITB) and Anthony Murphy (Department of Experimental Physics, NUI, Maynooth) and is concerned with the quasi-optical design and analysis of the Heterodyne Instrument for the Far Infrared (HIFI) on board the European Space Agency's Herschel Space Observatory, which is due for launch in 2007. The paper begins with an introduction to astronomy at submillimetre wavelengths followed by the science that will be carried out by HIFI.

Kevin Martin (ITB), in the second paper, examines the issues of general and Information Literacy among first year students in 3rd level education. He suggests interventions that may help to remediate the problems for some students and help them fulfil their potential. There is increasing recognition that many students entering 3rd level education have literacy difficulties. Also, there are those that have specific learning difficulties such as Dyslexia1 and Dyspraxia2. Consideration can also be given to an increasingly diverse student body with greater representation of mature and non-national entrants who may not have English as a first language: easier access for second level students with a consequent drop in academic abilities and to dropping literacy standards in the wider societal context.

The third paper, by Dr. Anna Herwig (TCD), notes that over the past decades it has become generally acknowledged that lexicon and grammar are inseparably linked, constituting a continuum of symbolic structures. Yet, a comprehensive integration of the two realms of knowledge appears to be a difficult task. Her paper offers a unified psycholinguistic perspective, which is centred on the mental lexicon, considering grammatical knowledge as part of the information structure of lexical items. It aims to model the complexity of lexical knowledge such that its perceived psychological reality, including various levels of linguistic description, becomes discernible. In the light of recent research undertaken in different linguistics fields, the mental lexicon can be described as that domain of language where the various dimensions of linguistic information meet. It follows that the elements of the lexicon need to be modelled as highly complex entities, including information on representational substance (conceptual, perceptual, and articulatory patterns) and combinatorial potential.

We hope that you enjoy the papers in this issue of the ITB Journal.

Dr. Brian Nolan
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Dublin 15

An Introduction to the Quasi-Optical Design of the HIFI Instrument for the Herschel Space Observatory

Gareth S. Curran[1], J. Anthony Murphy[2]

1. School of Informatics and Engineering, Institute of Technology, Blanchardstown
2. Department of Experimental Physics, National University of Ireland, Maynooth

Abstract

This paper is concerned with the quasi-optical design and analysis of the Heterodyne Instrument for the Far Infrared (HIFI) on board the European Space Agency's Herschel Space Observatory, which is due for launch in 2007. The paper begins with an introduction to astronomy at submillimetre wavelengths followed by the science that will be carried out by HIFI. The optical layout of HIFI is presented and the quasi-optical techniques used in the analysis of band 5 of the instrument are discussed, in particular, issues associated with the design and performance of the integrated lens antenna for this band. A power coupling efficiency calculation is carried out and the overall performance of the telescope is analysed.

1. Introduction

The Herschel Space Observatory is named after Sir Frederick William Herschel (1738 – 1822) who is, in a sense, the father of infrared astronomy (although he is probably most famous for his discovery of the planet Uranus in 1781). Herschel discovered the non-visible part of the electromagnetic spectrum while trying to determine whether different colours of light contained different amounts of heat by using a thermometer and a prism to disperse sunlight. To his surprise, he found that the region just beyond the red light seemed to have the highest temperature of all, a region supposedly devoid of sunlight.

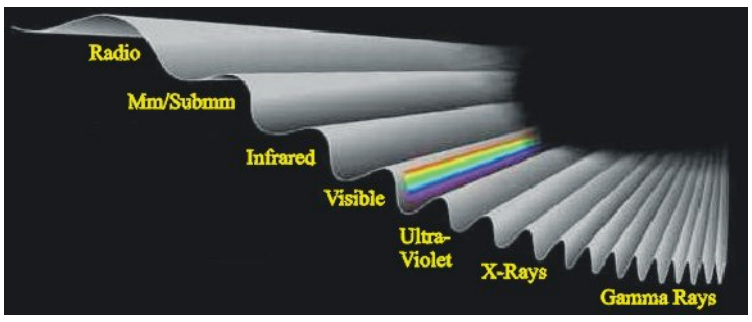


Fig. 1.1: Schematic diagram of the electromagnetic spectrum.

It is now known that the electromagnetic spectrum extends from long wavelength radio waves (λ~20m) to extremely high-energy gamma rays (λ~10^{-6}nm), as illustrated in Fig.1.1. The

visible region of the spectrum is very narrow ranging from 400nm to 700nm. The millimetre and submillimetre region, in which this paper concentrates, lies between the radio and infrared wavelengths. Strictly speaking, submillimetre refers to electromagnetic emissions at frequencies in the range of 300GHz to 1000GHz. The term *terrahertz* is now used to refer to frequencies greater than 1000GHz.

In 1932, Karl Jansky detected radio emissions from our own galaxy, the Milky Way [14]. This new phenomenon of observing non-visible radiation from space created a whole new branch of astronomy. Previously unseen objects in the universe could now be observed. In the last few decades the techniques of radio astronomy have been vastly improved and observable wavelengths have been getting shorter, which is technically more difficult. At the same time in optical astronomy the observable wavelengths have been getting longer, extending well into the infrared. It is only in the past twenty years that the area between these wavelengths, the submillimetre region, has been focused on and it is now possible to observe those wavelengths for which radio techniques become very difficult and optical techniques begin to break down. Sometimes this region is also referred to as the *far infrared*.

The continuum emission from dust clouds in the cold interstellar medium (ISM), produced by thermal radiation, can be viewed at submillimetre wavelengths. This emission has quite a broad band spectrum and has the characteristics of blackbody radiation. It therefore follows Wein's displacement law,

$$\lambda_{\max} T = 0.2898 \times 10^{-2}\, mK \qquad (1.1)$$

Thus the emission intensity peaks at a wavelength that is characteristic of the equilibrium temperature T. The temperature of interstellar dust clouds, 10K to 100K [5], is such that the intensity peaks in the submillimetre region. This is of great interest to astronomers as it is from these dust clouds that stars and planets are formed. This occurs when self-gravity overcomes thermal, turbulent and magnetic pressures and causes the cloud to collapse [10]. By observing these clouds at submillimetre wavelengths astronomers can investigate the very early stages of star birth. This continuum emission is most sensitively detected using bolometers, which are devices that simply absorb incident radiation and warm up. This changes their resistance so that when fed with a constant bias current a change in voltage is produced across the device [10]. They are usually held in a liquid helium cryostat at the focus of a large reflector to improve sensitivity to the levels required for doing useful astronomy.

Another type of radiation observed at submillimetre wavelengths has the form of line emission. This is associated with rotational transitions in ions, atoms and molecules with the

emission of photons when these species drop to a lower energy state. By examining the wavelength spectrum of the emitted radiation, astronomers can identify constituent elements of a source, or by measuring the Doppler shift can calculate the corresponding velocity.

Synchrotron radiation is yet another form observed at submillimetre wavelengths. It is caused by streams of particles moving at relativistic speeds through a magnetic field. Matter spiralling towards a black hole generates such emissions as does our own Sun as charged particles are ejected outward through its magnetic field. A group at NUI Maynooth has observed this radiation at sub-100GHz frequencies. Astronomers use synchrotron radiation to detect distant stars from Earth based observatories.

In conclusion, submillimetre astronomy is mainly used to observe the distribution, temperature and motion of dust, atoms and molecules in the universe and the very early stages of star formation in 'stellar nurseries', the dust and gas clouds in the interstellar medium often referred to as 'molecular' clouds. There are many telescopes that have been designed specifically for these observations. The James Clerk Maxwell Telescope (JCMT), the Caltech Submillimetre Observatory (CSO) and the Submillimetre Array (SMA), all of which are located on Mauna Kea at 4000m above sea level in Hawaii, and the Swedish-ESO Submillimetre Telescope (SEST) are all designed specifically for submillimetre wavelengths.

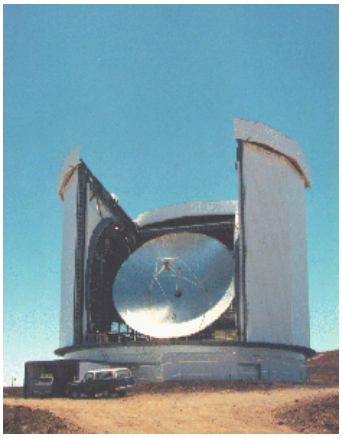


Fig. 1.2: The James Clerk Maxwell Telescope on top of Mauna Kea, Hawaii.

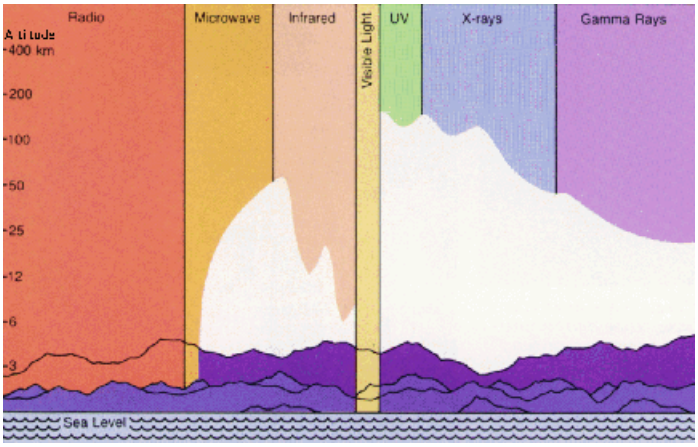
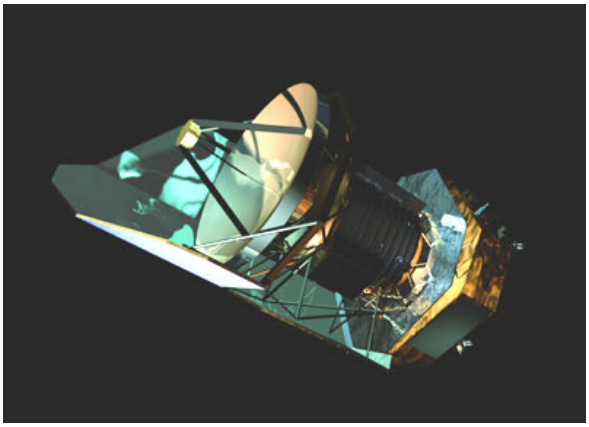


Fig. 1.3: Wavelengths and altitudes at which the atmosphere becomes opaque.

Although ground based observatories are extremely useful, the Earth's atmosphere places limits on the amount of radiation we can detect. Fig. 1.3 shows how the atmosphere is opaque to some wavelengths at different altitudes above sea level. For this reason it is desirable to take measurements as high above the ground as possible. Telescopes and detectors have been

flown in aircraft at very high altitudes and taken up to thirty-five kilometres above ground level in balloons, but the best solution is an orbiting satellite.

The Herschel Space Observatory is one such satellite. This ambitious project by the European Space Agency (ESA) will solve the mystery of how stars and galaxies are born. It will be launched on board an Ariane-5 from French Guiana and will be placed in an orbit at the 2nd Lagrangian point, L2, one and a half million kilometres away from Earth, a distance at which only one other space telescope has previously been placed (MAP arrived there on the 1st October 2001). It will observe wavelengths never comprehensively covered before. The satellite is approximately 7m high and 4.3m wide with a launch mass of around 3.25 tonnes. It will carry the Ritchey-Chrétien telescope, which has a primary mirror with a diameter of 3.5m, the largest satellite IR telescope ever built, and three focal plane experiments:



- PACS – *Photoconductor Array Camera and Spectrometer*
- SPIRE – *Spectral and Photometric Imaging Receiver*
- HIFI – *Heterodyne Instrument for the Far Infrared*

Fig. 1.4: An artist's impression of the ESA's Herschel Space Observatory (HSO).

These instruments will be cooled down to below 1K in a cryostat of superfluid liquid helium. This paper is mainly concerned with the science, operation and design of the HIFI instrument on the Herschel Space Observatory.

2. Science with HIFI

HIFI's superb spectral resolution (103 up to 107 or 300 – 0.03Km/s) coupled with its ability to observe thousands of molecular, atomic and ionic lines at submillimetre wavelengths makes it the instrument of choice to probe many of the key questions in modern astrophysics related to the cyclic interaction of stars and the interstellar medium. The instrument combines the high spectral resolving power of the radio heterodyne technique with quantum noise limited detection based on superconducting devices and state-of-the-art microwave technology. This makes it possible to provide continuous coverage from frequencies of

480GHz to 1250GHz in five separate bands. Two additional bands will also observe at 1410GHz to 1910GHz at an unrivalled spectral resolution. The table below (Table 2.1) shows the band number and its corresponding frequency coverage.

Band Number	1	2	3	4	5	6L	6H
Frequency (GHz)	480 – 642	640 – 802	800 – 962	960 – 1122	1120 – 1250	1410 – 1660	1660 – 1910

Table 2.1: Frequency coverage by different bands on HIFI.

One of the major molecules in the universe not observable from ground-based telescopes is H_2O. HIFI will obtain a complete inventory of the most important rotational lines of water and its isotopomers, therefore providing the possibility of tracing the evolution of the water molecule from its origins to its dissociation. The different water lines observed will probe vastly different environments, such as the atmosphere of Mars (Fig. 2.1), and the Orion Molecular Cloud (Fig. 2.2). Since H_2O is the major coolant in star forming regions, HIFI will explore the physics, kinematics and energetics of these regions.

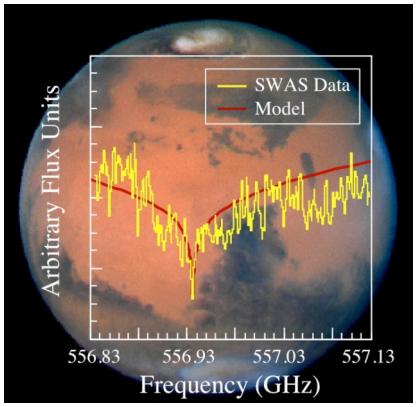


Fig. 2.1: SWAS observations of the 557GHz ground state line of water in the

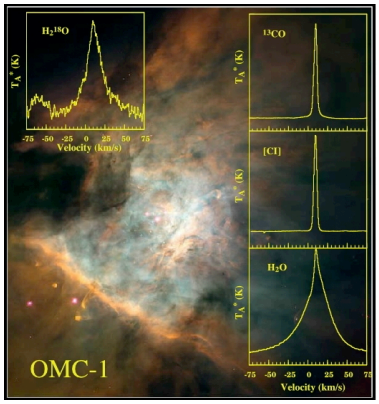


Fig. 2.2: SWAS observations of water Towards a region of high-mass star formation in the Orion Molecular

Apart from H_2O, HIFI will also investigate the origin and evolution of other molecules in the universe. This will be carried out by searching for low-lying ro-vibrational transitions of complex species such as polycyclic aromatic hydrocarbons. A survey of the molecular inventory of diverse regions will also be carried out, including shocked molecular clouds, comet tails, dense Photon-Dominated Regions (PDR's), hot cores and protoplanetary disks around newly formed stars, winds from dying stars and toroids interacting with Active Galactic Nuclei (AGN) engines.

Analysis of the interstellar medium (ISM) will also be undertaken by HIFI. It will measure the mass-loss history of stars from stellar winds and mass outflows which, rather than nuclear burning, dominate the gas and dust mass balance of the ISM, as well as regulating stellar evolution after the main sequence. The pressure of the interstellar gas throughout the Milky Way will also be measured, which will solve the puzzle of the intense galactic [CII] 158μm emission measured by COBE. The ratios of the $^{12}C/^{13}C$ and $^{14}N/^{15}N$ isotopes as a function of galactic radius will be determined for the Milky Way and other galaxies. This will constrain the parameters of the Big Bang and explore the nuclear processes that enrich the ISM.

To understand more about galaxies, HIFI will measure the far-infrared line spectra of nearby galaxies, such as *Centaurus A*, as a template for distant and possibly primordial galaxies. All of this science and astronomy would not be possible were not for the increasing advancement in technology and the use of heterodyne techniques.

3. Quasi-Optical Analysis Using Gaussian Beam Modes

To begin with, it is appropriate to give a brief explanation as to what *quasi-optics* or long wavelength optics actually entails. Quasi-optics deals with the propagation of a beam of radiation that is reasonably well collimated but has relatively small dimensions, transverse to the axis of propagation, when measured in wavelengths [2]. It spans the middle ground between geometrical optics, where the wavelength is assumed to be zero, and diffraction dominated propagation, where the wavelength is approximately equal to the systems dimensions. Quasi-optics therefore includes the situation of a beam of radiation whose diameter is only moderately large when measured in wavelengths.

For different regions of the electromagnetic spectrum, different approaches to understanding the physics involved in propagation are appropriate. Metallic conducting and dielectric waveguides are often used at microwave frequencies to guide the electromagnetic beam, but these structures become lossy at high frequencies because of the materials involved. The power loss per unit length of dielectric materials generally increases at least as fast as proportional to frequency, but loss proportional to the square of frequency is found in the millimetre and submillimetre range [2]. For a rectangular, metallic waveguide, the loss increases as frequency to the power of 1.5. This is where quasi-optics makes its appearance. It takes advantage of the essentially loss-less nature of propagation in free space. Lenses and mirrors are still used for focusing the propagating beam, but they are relatively well separated from each other and are quite thin so that the loss per unit length over which the beam travels is greatly reduced.

One quasi-optical analysis technique is the use of Gaussian beam mode theory, which was developed for the analysis of laser cavities in the 1960's. It was found to be both conceptually and computationally superior to diffraction integral techniques in the analysis of millimetre/submillimetre-wave quasi-optical systems [11]. Consider a monochromatic spatially coherent beam represented by the complex scalar field $E(x,y,z)$. This beam is composed of a linear sum of independently propagating complex modes represented by $\Psi_i(x,y,z)$, of the form,

$$E(x,y,z) = \sum_{0}^{\infty} A_i \Psi_i(x,y,z) \qquad (3.1)$$

where A_i are the mode coefficients and each mode has a transverse amplitude distribution whose envelope is a Gaussian function [7]. The sum of these amplitudes squared is a measure of how good a fit a synthesised beam is to the beam being analysed [4]. The modes are solutions to the wave equation appropriate to quasi-optical propagation.

In the derivation of Gaussian beam modes two important assumptions are made [11]. Firstly, the radiation is assumed to be moving as a paraxial beam whose cross-sectional size is not sufficiently large that it can be treated as an infinite plane parallel wave. By '*paraxial*' we mean that the beam is essentially moving along a given axis but with some diffraction taking place, so the beam spreads out into a small opening angle. Secondly, we assume the radiation can be represented as a scalar field.

The Gaussian beam modes are derived by finding modal solutions to the electric and magnetic wave equations in free space appropriate to paraxial propagation. It is always true that [8],

$$\nabla^2 \mathbf{E} = -\frac{1}{c^2}\frac{\partial^2 \mathbf{E}}{\partial t^2} \qquad (3.2) \qquad\qquad \nabla^2 \mathbf{B} = -\frac{1}{c^2}\frac{\partial^2 \mathbf{B}}{\partial t^2} \qquad (3.3)$$

If the source of the radiation is monochromatic, then the wave equation for the case of the electric field reduces to the Helmholtz equation,

$$\nabla^2 \mathbf{E} = k^2 \mathbf{E} = 0 \qquad (3.4)$$

where, $k = \frac{2\pi f}{c}$ (f is the frequency of the radiation and c is the speed of light). Assuming the electric field may be written in terms of independent scalar distributions $E(x,y,z)$, the three components of the electric field may be treated as scalar versions of the wave equation and therefore Eqn. 3.4 may be written as,

$$\nabla^2 E + k^2 E = 0 \tag{3.5}$$

If a wave is propagating in the *z*-direction then a solution of the form,

$$E = \Psi(x, y, z)\exp(-jkz) \tag{3.6}$$

is appropriate, where $\Psi(x, y, z)$ is a slowly varying function with respect to *z*. If we substitute this into Eqn. 3.5 we get,

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} - 2jk\frac{\partial \Psi}{\partial z} = 0 \tag{3.7}$$

or in polar co-ordinates,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial \Psi}{\partial r}\right) + \frac{1}{r^2}\left(\frac{\partial^2 \Psi}{\partial \vartheta^2}\right) - 2jk\frac{\partial \Psi}{\partial z} = 0 \tag{3.8}$$

where Ψ varies so slowly with respect to *z* that its second derivative can be neglected (paraxial approximation). The solutions to these equations are a set of modes analogous to the set of modes that characterise the propagation of radiation in a metallic waveguide. The precise nature of the modal solutions depends on the symmetry conditions governing the system and the co-ordinate system chosen [15].

For a system of Cartesian co-ordinates, the solution to this equation is given by a set of modes called *Hermite-Gaussian modes*, which are generally written as,

$$\Psi(x, y) = h_m\left(\frac{\sqrt{2}x}{W}\right)h_n\left(\frac{\sqrt{2}y}{W}\right)\exp\left(\frac{jkr^2}{2R}\right)\exp(j\phi_{mn}) \tag{3.9}$$

where *m* and *n* are transverse mode numbers and r^2 is the radial off-axis distance from the beam centre (i.e. $r^2 = x^2 + y^2$). *R* and *W* are slowly varying functions of *z* and how they evolve with *z* will be discussed further on. ϕ_{mn} is called the '*phase slippage*'. It is mode dependent and is given by the equation,

$$\phi_{mn} = (m + n + 1)\tan^{-1}\left(\frac{\lambda z}{\pi W_o^2}\right) \tag{3.10}$$

where W_o is the beam waist radius. The Hermite-Gaussian beam modes are orthonormal in the sense that,

$$\iint \Psi_{mn}\Psi_{m'n'}dxdy = \delta_{mm'}\delta_{nn'} \tag{3.11}$$

Therefore, for convenience we define the normalised Hermite-Gaussian function to be,

$$h_m(x,W) = \frac{1}{\sqrt{2^{m-0.5}\, m!\sqrt{\pi W^2}}} H_m\left(\frac{\sqrt{2}x}{W}\right)\exp\left(-\frac{x^2}{W^2}\right) \qquad (3.12)$$

where $H_m(\gamma)$ is a Hermite polynomial of order *m* in γ (as defined in Gradsteyn *et al* [3]).

Alternatively, for a system of cylindrical polar co-ordinates, the solution to the wave equation can be written in terms of a set of modes called *Laguerre-Gaussian modes*, which are given by,

$$\Psi^c_{mn}(r,\vartheta,z) = \frac{2}{W\sqrt{\pi}}\left(\frac{2r^2}{W^2}\right)^{\frac{n}{2}} l_n^m\left(\frac{2r^2}{W^2}\right)\cos(m\vartheta)\exp\left(-\frac{r^2}{W^2}\right)\exp\left(-\frac{jkr^2}{2R}\right)\exp(j\phi_{mn}) \qquad (3.13)$$

$$\Psi^s_{mn}(r,\vartheta,z) = \frac{2}{W\sqrt{\pi}}\left(\frac{2r^2}{W^2}\right)^{\frac{n}{2}} l_n^m\left(\frac{2r^2}{W^2}\right)\sin(m\vartheta)\exp\left(-\frac{r^2}{W^2}\right)\exp\left(-\frac{jkr^2}{2R}\right)\exp(j\phi_{mn}) \qquad (3.14)$$

where,

$$l_n^m\left(\frac{2r^2}{W^2}\right) = \left(\frac{(m+n+1)!}{n!}\right)L_n^m\left(\frac{2r^2}{W^2}\right) \qquad (3.15)$$

with $L_n^m(\varepsilon)$ being an associated Laguerre polynomial of order *m* and degree *n* in ε [3]. In this case Ψ^c_{mn} and Ψ^s_{mn} are orthonormal as are the Hermite-Gaussian modes.

For a cylindrically symmetric system the solution to the Laguerre-Gaussian modes can be written as,

$$\Psi_m(r) = \frac{1}{W}\sqrt{\frac{2}{\pi}} l_m^0\left(\frac{2r^2}{W^2}\right)\exp\left(-\frac{r^2}{W^2}\right)\exp\left(-\frac{jkr^2}{2R}\right)\exp(j\phi_m) \qquad (3.16)$$

where $l_m^0(\gamma)$ is a normalised zeroth order Laguerre polynomial of degree *m*. Again we must take into account the phase slippage when propagating the Laguerre-Gaussian modes and this can be written as,

$$\phi_m = (2m+1)\tan^{-1}\left(\frac{\lambda z}{\pi W_o^2}\right) \qquad (3.17)$$

where *z* is the axis of propagation.

For propagation, we consider the fundamental mode of the Hermite-Gaussian mode set. It has a Gaussian profile and is the simplest mathematical solution to the Helmholtz equation. This mode is given by,

$$\Psi_0(x,y) = \frac{1}{W}\sqrt{\frac{2}{\pi}}\exp\left(-\frac{r^2}{W^2}\right)\exp\left(-\frac{jkr^2}{2R}\right) \qquad (3.18)$$

and represents a Gaussian beam propagating in the *z*-direction, whose intensity profile does not change as it propagates except for a re-scaling factor as shown in Fig. 3.1 & Fig. 3.2.

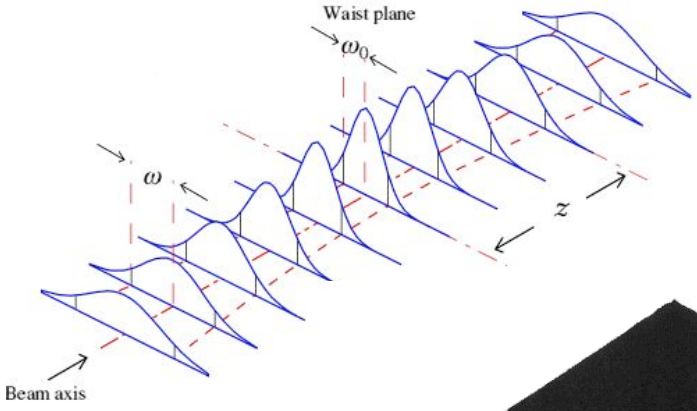


Fig. 3.1: Profile of the fundamental Gaussian as it propagates in free-space.

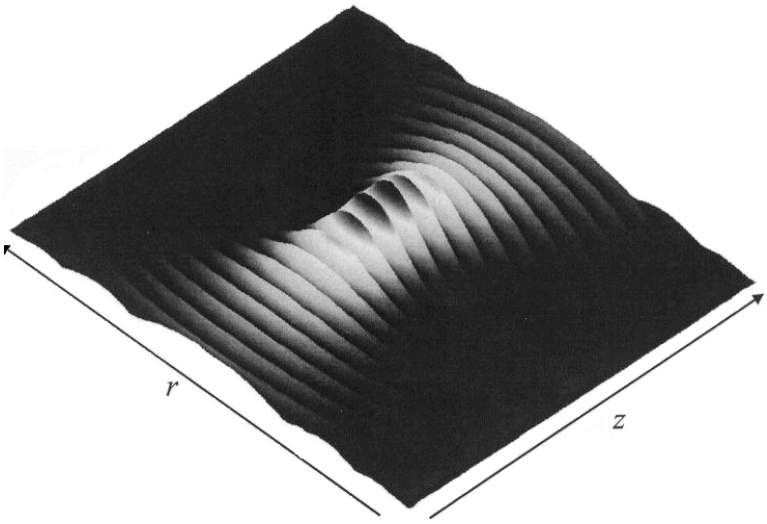


Fig. 3.2: Propagating fundamental Gaussian beam mode showing both the change in width and the radius of curvature.

The off-axis distance at which the amplitude is equal to $1/e$ is given by the beam width parameter, W. This parameter varies as the beam propagates along the *z*-axis and at some distance *z* away from the waist is given by,

$$W^2(z) = W_o^2\left[1+\left(\frac{\lambda z}{\pi W_o^2}\right)^2\right] \qquad (3.19)$$

where W_o is the radius at the waist at which W is a minimum, which is known as the *beam waist radius*.

Another property of the beam that varies as it propagates is called the *phase front radius of curvature*, R, which describes the curvature of the equiphase surface of the beam [15]. The expression for R is written as,

$$R(z) = z\left[1 + \left(\frac{\pi W_o^2}{\lambda z}\right)^2\right] \tag{3.20}$$

At the beam waist, the radius of curvature is infinite and the beam is similar to a plane wave (Fig. 3.3). At a large distance from the waist radius, the radius of curvature is just equal to that distance, so that the beam looks like a spherical wave spreading from a point source at the waist (Fig. 3.4).

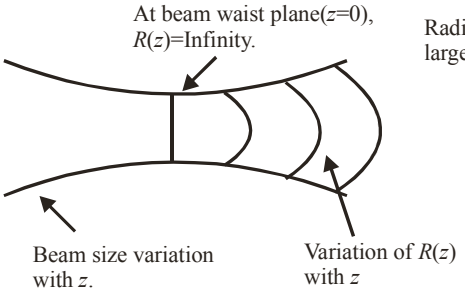


Fig. 3.3: Variation in R(z) as the *beam propagates along the z-axis.*

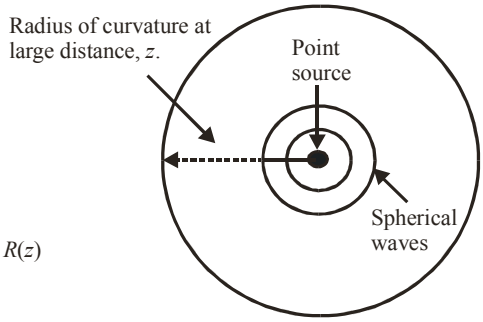


Fig. 3.4: At large values of z, the radius *of curvature has the same value as z.*

When propagating several modes, it is very important to include the effects of the phase slippage. Effectively different modes, Ψ_{mn}, have different phase velocities. If a field consists of a sum of modes, the relative phase between component modes varies along the axis of propagation since the phase slippage term (Eqn. 3.17) is a function of z and is mode number dependant. This results in the amplitude distribution of the composite field altering shape (or form) with z, as in diffraction theory [9].

As an example of the application of Gaussian beam mode analysis we consider the diffraction pattern produced by a straight edge placed in the path of a plane wave, $E(x, y, z) = E_0 \exp(-jkz)$. This can clearly be regarded essentially as a one-dimensional problem. We use a Hermite-Gaussian modal set and consider an expansion of the form [9],

$$E(x,z) = \sum_m A_m h_m(x, W(z)) \exp\left[-jk\left(z + \frac{x^2}{2R(z)}\right) + j\left(m + \frac{1}{2}\right)\tan^{-1}\left(\frac{\lambda z}{\pi W_o^{\,2}}\right)\right] \tag{3.21}$$

In this case the phase slippage term is not incorporated into the amplitude coefficients. If we are only interested in the plane where the obstruction lies, and we are taking this to be the position of the beam waist, then $z = 0$ and the expression reduces to,

$$E(x) = \sum_m A_m h_m(x, W_o) \tag{3.22}$$

where the A_m values are calculated by,

$$A_m = \int_0^\infty f(x) h_m(x, W_o) dx \tag{3.23}$$

letting $f(x) = 1$ for a plane wave. In this case the straight edge is placed at $x = 0$ and lies along the *y*-axis. Depending on the number of modes used to reconstruct the field, the reconstruction will fail beyond a certain value of *x* since modes only reach a finite distance off axis (determined by mode number and *W*). Therefore, it is essential to use the correct number of Hermite-Gaussian modes.

A reconstruction of a field with a waist of 1mm and wavelength of 0.1mm is shown in Fig. 3.5. The field is shown at the plane of a straight edge along the *y*-axis as described above and sixty Hermite-Gaussian modes were used. Clearly because of the finite number of modes used the edge is not a discontinuity. The clear ringing seen is similar to that seen in Fourier

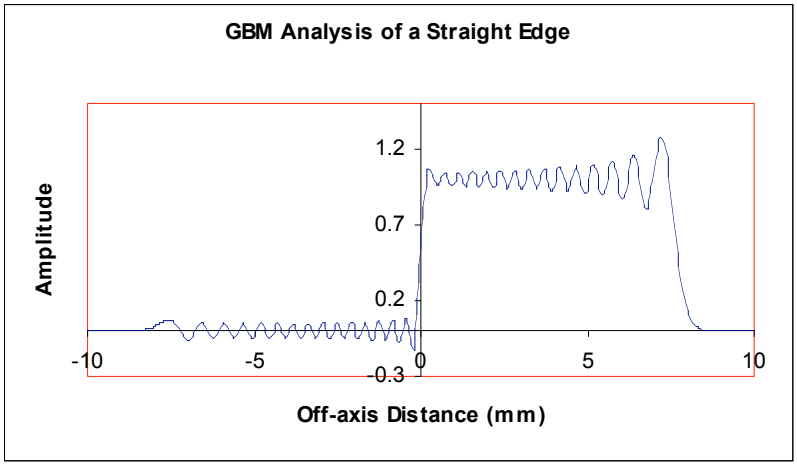
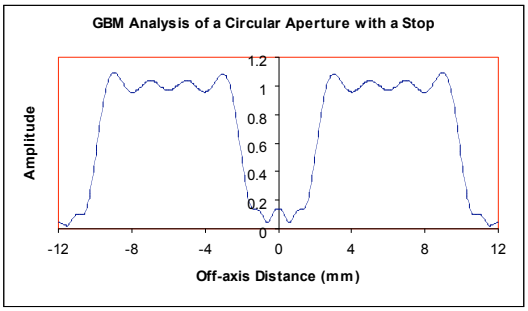


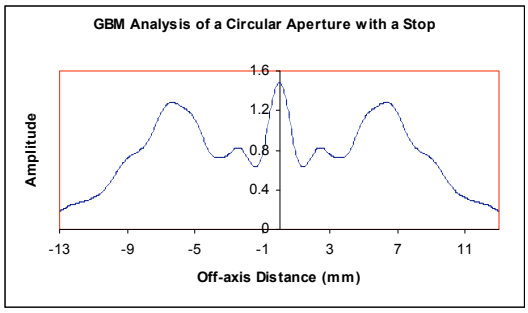
Fig.3.5: Reconstruction of a field at the plane of a straight edge which lies along the y-axis (waist = 1mm, λ = 0.1mm).

Series when reconstructing sharp edges. The ringing period depends on the number of modes used.

Clearly, sharp edges are difficult to reconstruct in any modal approach. However, away from planes where fields are clipped the modal method approaches a very good approximation to the diffracted field. It does underline however, that an appreciation of the limitations of the numerical approach (i.e. only a finite number of modes being used in the modal sum) is

important to any analysis. A similar approach was used to analyse a system of a circular aperture with a stop, analogous to the layout of a Cassegrain telescope, the results of which are shown in Fig. 3.6, Fig. 3.7 and Fig. 3.8. The beam was assumed to have a wavelength, λ, of 1mm and a waist radius of 9mm with one hundred Laguerre-Gaussian modes being used in the reconstruction. The circular aperture had a radius of 10mm and the stop a radius of 2mm.





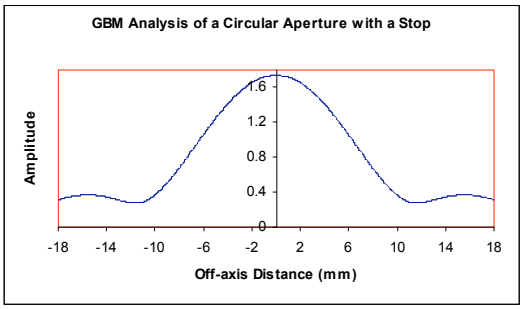


Fig. 3.6 (top left): Reconstruction of the field at the plane of the circular aperture.

Fig. 3.7 (top right): Reconstruction of the field at a distance of 20mm (20λ) from the plane of the circular aperture.

Fig. 3.8 (bottom): Reconstruction of the field at a distance of 200mm (200λ) from the plane of the circular aperture. This is the far field.

In conclusion, both the straight edge and the circular aperture are examples of how Gaussian beam mode analysis proves very useful. We can easily switch from Cartesian co-ordinates, as in the case of the straight edge, to polar co-ordinates for systems with circular symmetry. It is also possible to analyse focussing optical components such as curved mirrors and lenses, which allows Gaussian beam modes to be used in the analysis of a complete optical system.

Other techniques used for quasi-optical analysis include ray tracing, Fresnel diffraction and physical optics. Each method has its own advantages and disadvantages but used together form a powerful set of tools for analysing different properties of the optics in question. For this reason, in the analysis of a complete system, many different methods must be used for a full understanding of the underlying processes. The following sections will show how these techniques of quasi-optical analysis were put to use in the design and analysis of the integrated lens antenna on the HIFI instrument.

4. The Optical Layout of HIFI

Alongside the Herschel Space Observatory inside the launch vehicle will be another satellite called PLANK. Therefore, due to the small size of the Ariane-5 vehicle and the enormous cost of putting satellites into space, the size of the HSO is restricted and therefore so too is the size of the HIFI optics. As the initial optical design was undertaken by TPD (TNO, the Institute of Applied Physics, Delft) using ray tracing and geometrical optics in the limit where $\lambda = 0$, it was crucial to analyse the system more realistically, taking the long wavelength of the submillimetre radiation into account. The geometric analysis is not completely adequate to describe the propagation of beams where diffraction effects need to be considered.

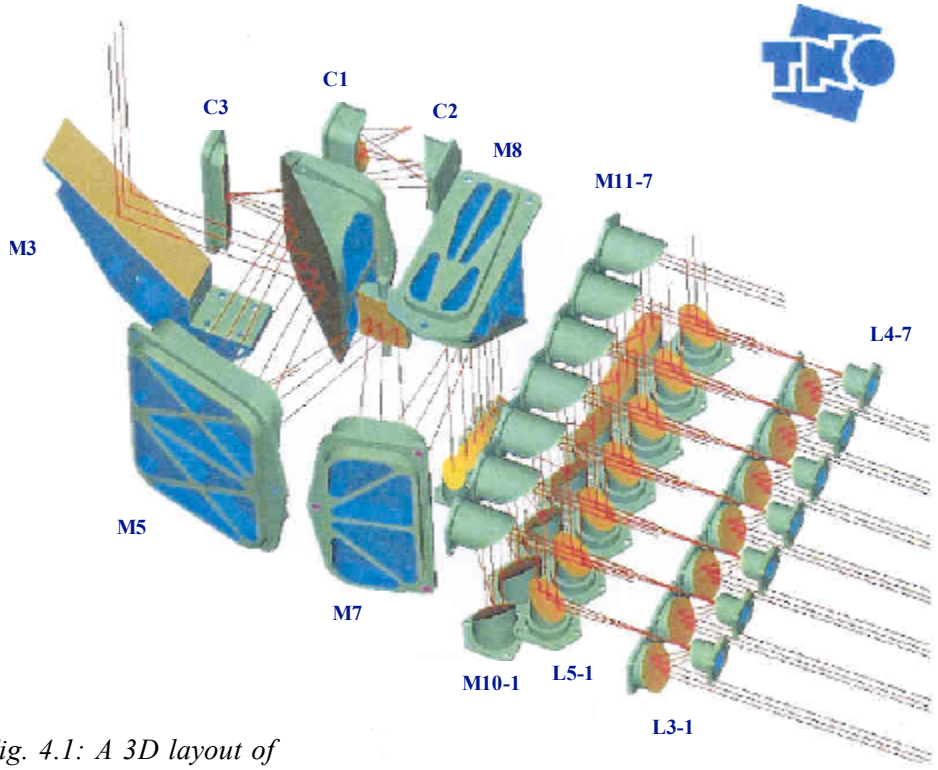


Fig. 4.1: A 3D layout of the HIFI optical system.

This paper is mainly concerned with the integrated lens antenna and mirror system in band 5 of HIFI. Since this band has the lowest frequency of all those channels containing lens antennas, it will suffer more severely from diffraction problems and therefore, if the design can be verified at this wavelength, it can be adapted to the other bands. The full HIFI focal plane optical system consists of a number of distinct subsystems: the Common Optics Assembly (COA), the Local Oscillator (LO) Optics and the Mixer Assembly (MA). The COA is basically a relay system directing radiation to seven different mixer assemblies corresponding to the

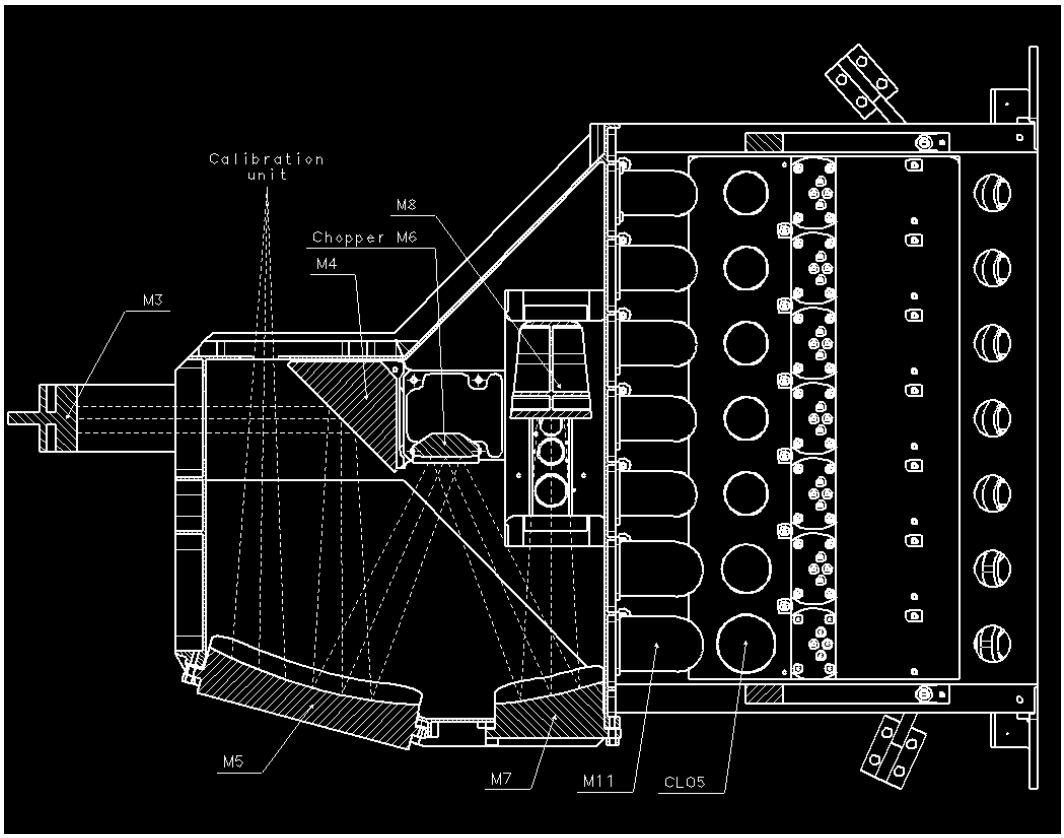


Fig. 4.2: Horizontal cross-section of the common optics and cold LO optics of HIFI

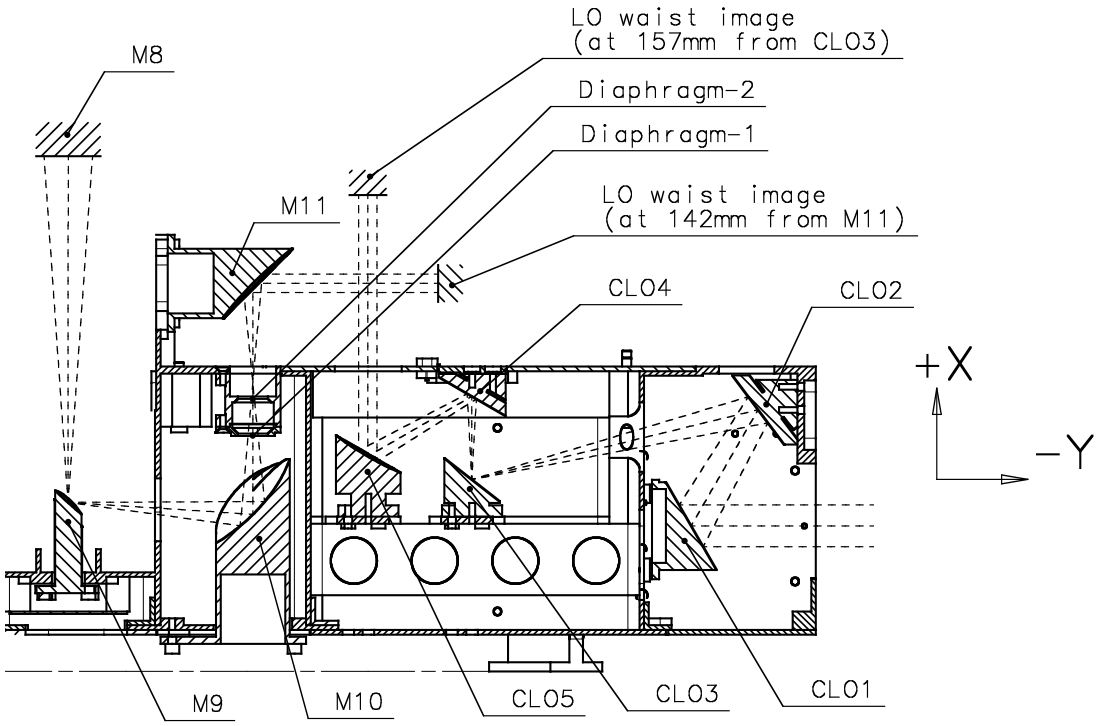


Fig. 4.3: The channel splitting optics and cold LO optics HIFI's channel 4.

channels of HIFI. Within the mixer assemblies (Fig. 4.4), the collimated telescope beam, B CHTEL (Beam Channel TELescope), and the local oscillator beam, B CHLO (Beam Channel Local Oscillator), are coupled and directed to two mixer subassemblies. In channels 5, 6L and 6H, a silicon lens focuses the beam to the submillimetre receiving planar antenna glued to the back surface of the lens.

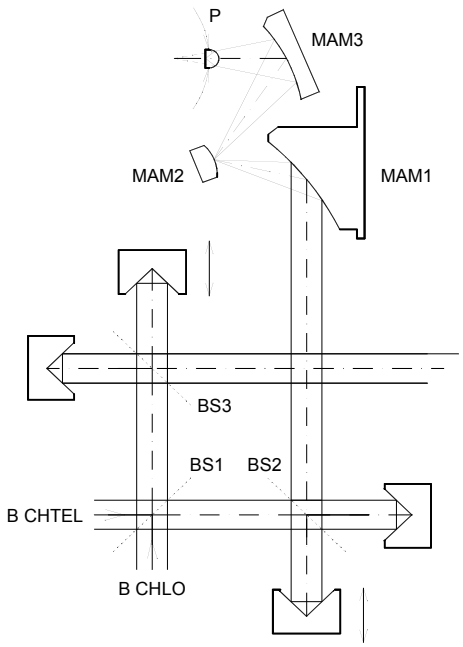


Fig. 4.4: The Mixer Assembly (MA) optics for channels 5, 6L and 6H of HIFI.
Only one mixer subassembly is shown, which consists of mirrors MAM1, MAM2 and MAM3. The beam is then

5. Design and Analysis of the Integrated Lens Antenna

The initial design concept for the integrated lens antenna for band 5 of HIFI was proposed by Caltech (California Institute of Technology). This system consisted of a hyperhemispherical silicon lens with a double-slot feed antenna. The lens had a diameter of 5mm and with a refractive index of 3.14 for silicon, it required an extension length of 0.7316mm using the equation,

$$L_h = \frac{r_S}{\sqrt{\varepsilon_r}} \qquad (5.1)$$

where r_S is the radius of the spherical portion of the lens and ε_r is the relative permittivity of the material. The operating frequency was assumed to be 1185GHz. To reduce reflection losses the lens had a quarter-wavelength matching layer. The double-slot planar feed had a length $l = 77.4\mu m$, a separation of $44.2\mu m$ and the width of the slots was set at $4\mu m$. This

system produces a beam with an f-number of 2.5 or, from Eqn. 5.2, an opening angle of 22.6°.

$$f-number = \frac{f_{eff}}{D_{primary}} = \frac{l_s}{D_{\sec ondary}} = \frac{1}{2\tan\left(\frac{\theta}{2}\right)} \tag{5.2}$$

One problem with this f-number is that because it is quite short, it gives rise to a proportionally small focal spot, causing difficulty in the alignment process of the optical system. Bands 1 to 4 have a have a longer f-number of 4.25. Having the same f-number for band 5 would make for easier testing and would allow the same optical design to be used for all channels. However, by having a longer f-number, the system would suffer from a reduction in the coupling efficiency and an increase in reflection loss at the matching layer and air interface. To investigate this further, two new lens designs were analysed, both of which were elliptical and produced a beam with an f-number of 4.25, which is shown in Table 5.1.

Lens Type	Hyperhemispherical	Elliptical	Elliptical
F-Number	2.5	4.25	4.25
Half Short Axis	2.5mm	2.819mm	2.439mm
Half Long Axis	2.5mm	2.846mm	2.496mm
Diameter	5.0mm	5.638mm	4.878mm
Extension	0.731mm	0.851mm	0.673mm
Matching Layer	Quarter-wavelength	None	None
Lens Name (for referral in paper)	HypHem	Ell#1	Ell#2

Table 5.1: Lens data for a hyperhemispherical lens and two elliptical lenses.

In reality the system will be receiving radiation, however, in its analysis we made use of the Theorem of Reciprocity [6], which allowed it to be treated as a transmitter rather than a receiver. The first step in this procedure was to produce the far field radiation patterns of each of the integrated lens antennas, which was carried out using a program called PILRAP (written by Van der Vorst [13]). This software allows the user to input both the lens and

antenna specifications and then uses ray tracing inside the lens followed by physical optics to generate the far field. The far field patterns for all three lenses are shown below (Fig. 5.1).

Although the far field patterns had the required beam width, it was important to ensure that there was no refocusing of the beam in the near field, which could lead to a mismatch with the optics. To check qualitatively for any such effects a ray tracing analysis of the lens designs was also carried out using a

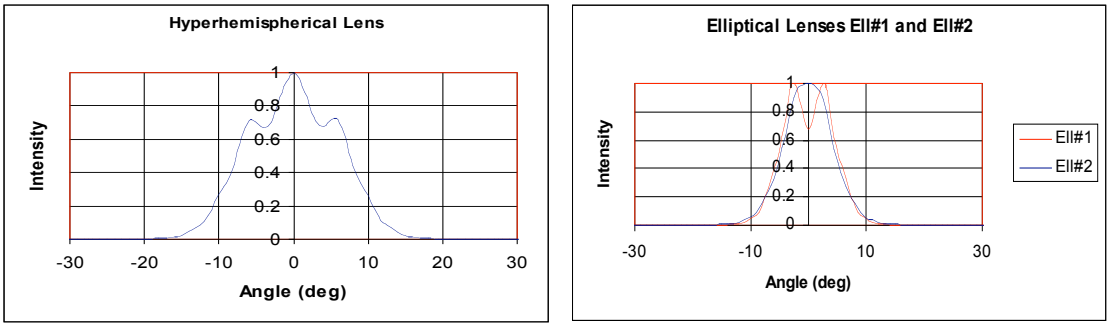


Fig. 5.1: The far field radiation patterns generated by PILRAP for all three lens systems.

commercially available software program called ZEMAX®. This program treats the optical system in question as a system of different 'surfaces' whereby the first is the object surface where the source is located and the final surface is the image surface. For each of these and the surfaces in between, the user may input a 'thickness', a radius of curvature, a conic constant and a material from which the surface, i.e. the component, is made. By giving the surface a radius of curvature and a thickness, the radius of the dielectric lens can be defined, as can the thickness of the extension length. The ray tracing may then be carried out from the object surface to the image plane.

Surface	Type	Radius	Thickness	Glass	Semi-Diameter	Conic Const.
OBJ	STANDARD	0.00E+00	1.00E-05		2.86E-02	0.00E+00
STO	STANDARD	0.00E+00	8.51E-01	SILICON_3.416	2.50E-03	0.00E+00
2	STANDARD	0.00E+00	2.85E+00	SILICON_3.416	2.82E+00	0.00E+00
3	STANDARD	-2.79E-01	2.87E+01		2.82E+00	-1.89E-02
IMA	STANDARD	0.00E+00	0.00E+00		2.97E+00	0.00E+00

Table 5.2: Surface data as defined in ZEMAX for the elliptical lens Ell#1.

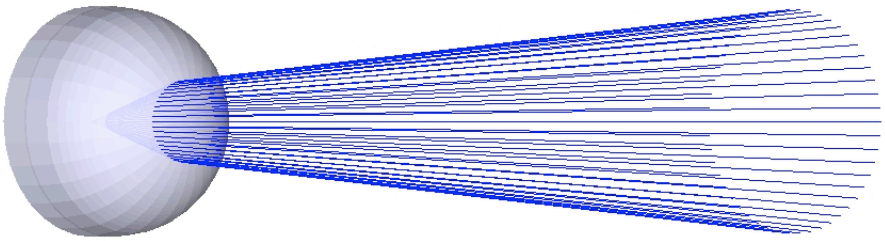


Fig. 5.2: 3D image of the ray tracing analysis carried out on lens Ell#2.

Since the ray tracing showed that there were no unwanted focusing properties (Fig. 5.2) for the three lenses, a Gaussian beam mode analysis was carried out to reproduce the waist field, given the far field pattern from PILRAP. The first step in this is to calculate the Gaussian beam mode coefficients and then synthesise the far field pattern to confirm the results of the calculation. Using the Gaussian beam expansion, the near field can then be produced quite simply. However, there is one subtlety with this approach. The phase front radius of curvature in the far field is not flat with respect to a spherical wave at the PILRAP reference surface in the lens antenna. Thus when the near field is reproduced at the reference surface, it will not be the field at the true beam waist. To overcome this problem, the phase variation in the far field as output by PILRAP was matched to a spherical phase error, which was then subtracted to 'flatten out' the phase. This effectively meant that the new reference plane, with respect to which the beam pattern was calculated, was very close to the true waist position [1]. Both the far field and near field patterns are shown in below as calculated using a Gaussian beam analysis. The total power contained in the fundamental mode, P_0, was also calculated using the equation

$$P_0(in\%) = \left(|A(0)| / \sum_m |A(m)|^2 \right) \times 100 \qquad (5.3)$$

which of course is also a measure of the Gaussicity of the beam. The results of this calculation are shown in the table below.

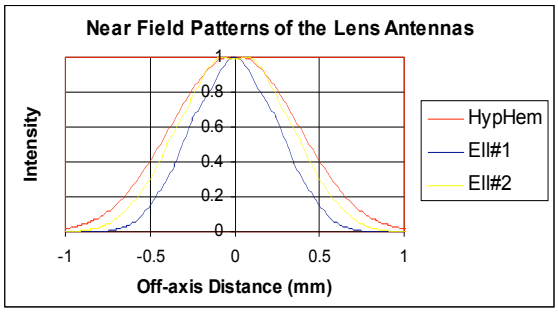


Fig. 5.3: Near field pattern of all three lenses as calculated using Gaussian beam

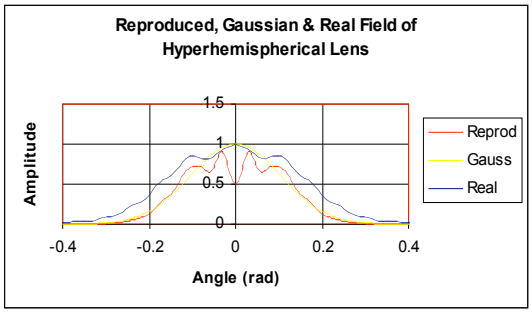


Fig. 5.4: Real far field and reproduced far field of HypHem along with a Gaussian

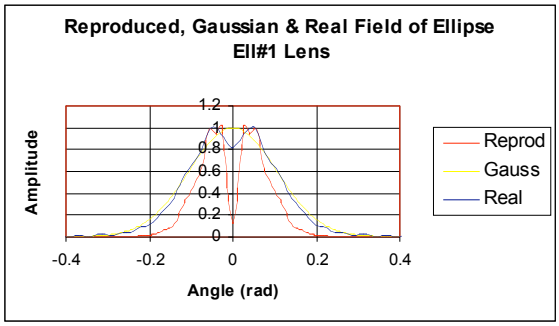


Fig. 5.5: Real far field and reproduced far field of Ell#1 along with a Gaussian

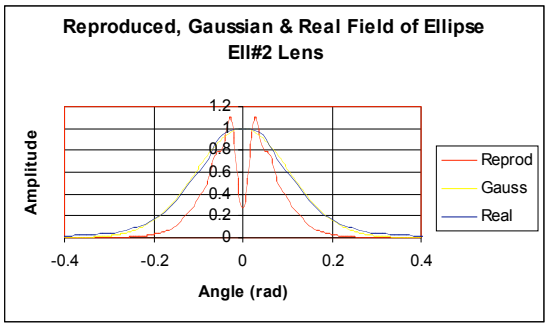


Fig. 5.6: Real far field and reproduced far field of Ell#2 along with a Gaussian

Lens Name	Waist Radius θ_0 (rad)	Power in Fundamental (as % of total power)
HypHem	0.175	87.95
Ell#1	0.130	94.82
Ell#2	0.140	95.4

Table 5.3: The value of θ_0 and the total power in the fundamental mode for each of the lens types.

Having generated the field at the beam waist plane it then had to be propagated through the three mirrors of the mixer subassembly of HIFI's band 5. This was achieved by using a program called GLAD® (General Laser Analysis and Design). Unlike geometrical optical codes, which represent the optical beam as rays, GLAD® represents the optical beam by the complex amplitude of the optical wavefront. However, it is not specifically designed for the submillimetre region of the spectrum and some functions such as calculating aperture

efficiencies and coupling efficiencies are not possible. To propagate the beam, a starting point and arbitrary output plane are entered, as well as the geometrical parameters of the optical system. The components of the system are then modelled in 3D space with the correct orientation and the desired field (in this case the beam waist field calculated earlier) is imported.

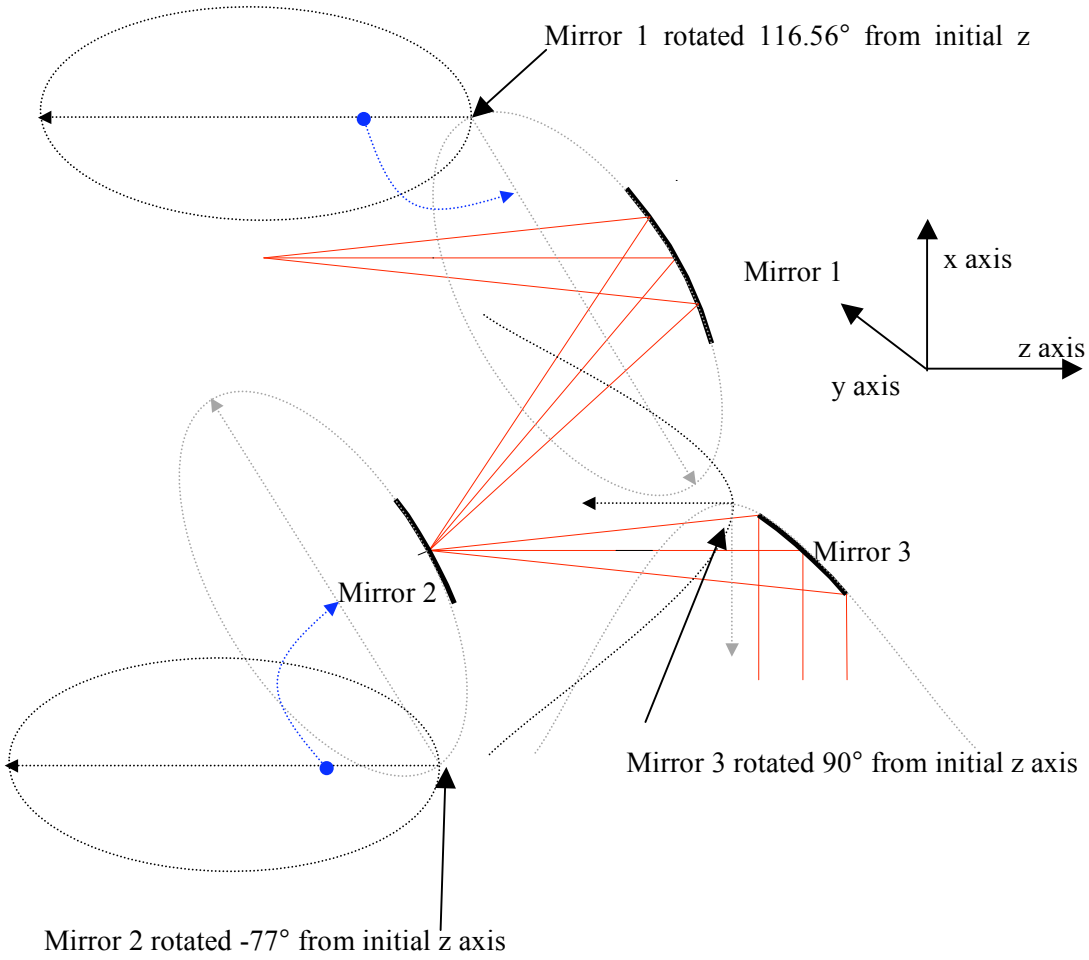
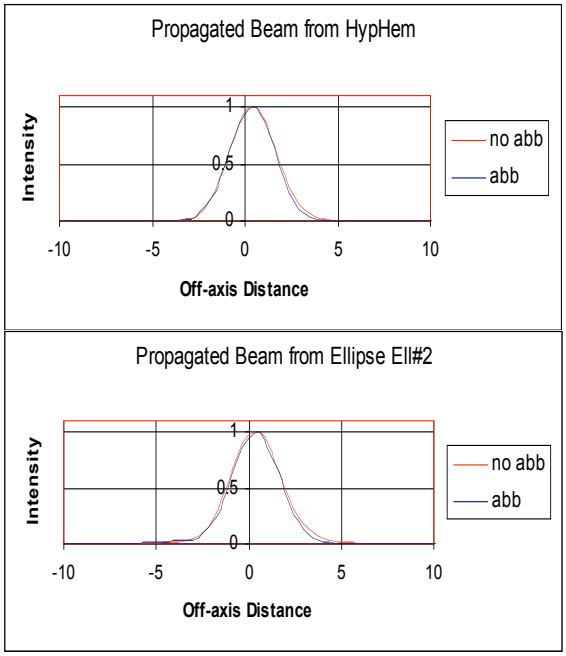


Fig.5.7: Mirror layout of the mixer subassemblv of band 5 as set in GLAD [12].

To compute the telescope aperture efficiency we need to determine the coupling between the telescope signal beam (from the sky), as calculated by N. Trappe [12], with the beam from the lens antenna, having been propagated through the mixer subassembly optics as shown in Fig. 5.8. For two fields, $\sum A_m \psi_m$ and $\sum B_m \psi_m$, which are not normalised, the total fractional power coupling efficiency is calculated by,

$$\eta_{12} = \frac{\left| \sum_m A_m B_m^* \right|}{\sum_m |A_m|^2 \times \sum_b |B_m|^2} \qquad (5.4)$$

This calculation was carried out for the sky beam with the beam from the hyperhemispherical lens and both beams from the elliptical lenses, with and without aberrational effects. The power coupling results are shown in Table 5.4



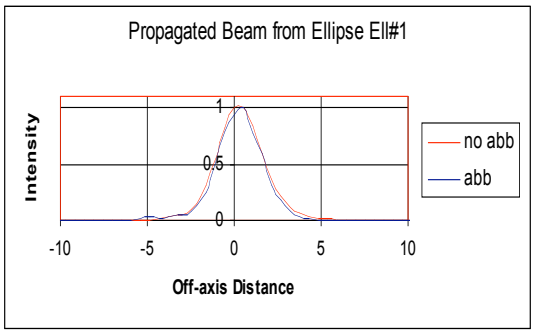


Fig. 5.8: Graphs showing the beams from the hyperhemispherical and two elliptical lens antennas as propagated to the diplexer plane by GLAD. The beams are shown with and without aberration.

Calculated Power Coupling Efficiencies		
	Excluding Aberration %	**Including Aberration %**
HypHem with Sky	80.79	71.59
Ellipse Ell#1 with Sky	77.64	76.40
Ellipse Ell#2 with Sky	74.20	71.68

Table 5.4: Power coupling efficiencies as calculated using Gaussian beam mode coefficients.

6. Conclusion

In this paper we discussed the function of the HIFI instrument on board the Herschel Space Observatory and the astronomy that will be carried out at submillimetre wavelengths. The techniques used in the analysis of quasi-optical systems were discussed with a particular emphasis on Gaussian Beam Mode Theory. These techniques were then applied to the mirror and lens antenna configuration found in HIFI's band 5, with attention given to three different lens designs.

As shown in the previous section, the different lens designs produce beams that couple with different efficiencies to the beam from the sky. In the case of the original hyperhemispherical lens, a coupling efficiency of 80.79% is achieved when neglecting aberration effects. This coupling efficiency is greater than that for either of the other two lens designs, which produce beams with 77.64% and 74.20% efficiency, again neglecting aberration. However, if we examine the efficiency of the beam produced by the elliptical lens Ell#2 and the original hyperhemispherical lens, and take into account the effects of aberration, then clearly there is not much difference between their coupling efficiency values of 71.59% and 71.68% respectively. A difference of 0.9% is obtained, whereas elliptical lens Ell#1 produces a beam with an efficiency of 76.40% (including aberration), yielding a difference of approximately 5% from the other two designs.

This analysis has shown that all three lenses produce beams with quite a high power coupling efficiency. It has also proved that the effects of aberration in the mixer subassembly optical system are large enough not to be neglected, as they will affect the performance of the telescope. Therefore, on choosing a lens design for band 5 of HIFI, it must be noted that it is the elliptical lenses that produce beams with the longer f-number. This was one of the main reasons for changing the original lens design. It can therefore be placed directly into an optical system with the same mirror configuration as the lower frequency bands and will couple as effectively as the lens with the shorter f-number, that is, the original hyperhemispherical lens as proposed by Caltech, in the optical system currently being used in band 5.

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The work described in this paper was carried out in collaboration with the Submillimetre Space Optics group at the National University of Ireland Maynooth and is ongoing. Other collaborators include ESTEC, SRON and TPD in the Netherlands. A special thanks is extended to Dr. Neil Trappe, Dr. Criéidhe O'Sullivan and Mr. Bill Lanigan. The authors would also like to acknowledge the financial support of Enterprise Ireland and the European Space Agency through a PRODEX award.

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Is the collage arund the korner just de sam? A study of General Literacy and Information Literacy in the year one Horticulture cohort at the Institute of Technology, Blanchardstown

Kevin Martin,

Lecturer in Communications

Institute of Technology Blanchardstown

Abstract

This paper examines the issues of general and Information Literacy among first year students at the Institute of Technology Blanchardstown, Dublin, Ireland in the School of Engineering and Computing. It specifically looks at the first year Diploma in Horticulture intake and briefly compares these to other cohorts in the school. It seeks to tentatively establish the percentages of students who are presenting with literacy difficulties. It suggests interventions that may help to remediate the problems for some students and help them fulfil their potential.

Introduction

There is increasing recognition that many students entering third level education have literacy difficulties. That they present with these difficulties is recognised as multi causational. There are those that have specific learning difficulties such as Dyslexia[1] and Dyspraxia[2]. Consideration can also be given to an increasingly diverse student body with greater representation of mature and non-national entrants who may not have English as a first language: easier access for second level students with a consequent drop in academic abilities and to dropping literacy standards in the wider societal context. Heretofore, it may be argued that third level staffs have viewed literacy as the concern of second level instruction. This viewpoint may be challenged in the light of rapid socio-cultural changes, student profiles and educational research. It ignores the fact that literacy skills develop throughout our lives and should respond to the demands of specific contexts and disciplines. It runs counter to avowed policies of lifelong learning and encouragement of participation in third level education of previously marginalised groups such as those mature students who may have had limited formal academic instruction in the past. Such a viewpoint would also seem to compromise policies of inclusion of ethnic minorities and non-national students in the student body. This paper seeks to analyse the literacy profiles of first year students at the Institute of Technology

Blanchardstown in the school of Informatics and Engineering with a specific focus on the Horticulture cohort for the academic year 2004/2005. Comparisons will be made between students who have followed the traditional leaving certificate entry and those who have taken non-traditional pathways including mature and second chance learners, non-national students who may have English as a second language and Post Leaving Certificate Course (PLC) [3] students.. It will investigate whether there is a mismatch between literacy levels that pertain and the demands of courses at the Institute of Technology Blanchardstown. It will make comparisons with similar studies internationally. There have been no similar studies completed in Ireland to date as far as can be ascertained. Consideration will be given to staff experiences and expectations. Finally, the current academic provision and support system will be reviewed and suggestions made as to how to address any deficiencies identified.

Defining literacy

Definitions of literacy have changed over time in parallel with changes in our society, economy and culture. The growing acceptance of the importance of lifelong learning has expanded views and demands. Literacy is no longer seen as an ability that is developed during the early school years but as an advancing set of skills, knowledge, and strategies those individuals build on throughout their lives in various contexts. These may vary from interaction with their peers to engaging with the larger communities in which they participate.

Historians remind us that the types and levels of literacy skills necessary for economic participation, citizenship, parenting, and individual advancement in 1800 were different from those required by 1900 and from those required in the year 2000 and beyond. We live in a technologically advancing world. Both the number and types of written materials are growing and increasing numbers of citizens are expected to use information from these materials in new and more complex ways.

As Resnick and Resnick (1977) point out, literacy in its earliest form consisted of little more than signing one's name. It was not until much later that fluent oral reading became important, and not until the 20th century that reading to gain information was required. The 2003 National Assessment of Adult Literacy defines literacy as 'using printed and written information to function in society, to achieve one's goals, and to develop one's knowledge and potential'. The revised Irish Primary Curriculum (1999) puts it bluntly: literacy is the ability to read and write. This is our fundamental concern: can third level students read and write well enough to function at this level? While these definitions are clear-cut, literacy is a more complex concept than they allows for.

Literacy is often conceived of as a discrete set of skills and knowledge: something you have or don't have (literate/illiterate) or something that exists on a single scale (degrees of literacy). However research in 'new literacy studies' shows it to be more than a set of decoding skills. Reading and writing are recognized as complex mental operations but also rooted in particular social contexts and purposes. The Irish National Adult Association for Adult Literacy (NALA) [4] literacy as 'the integration of listening, speaking, reading, writing and numeracy' (2004;pg 2) Furthermore, they suggest that it encompasses aspects of personal development: social, economic, and emotional and is concerned with improving self-esteem and building confidence. This conception of literacy goes far beyond mere technical skills of communication. The underlying aim of good literacy practice is to enable people to understand and reflect critically on their life circumstances with a view to exploring new possibilities and initiating constructive change. Similarly, the benchmark study, The International Adult Literacy Survey (IALS), which is described below, views literacy as a particular capacity and mode of behaviour: the ability to understand and employ printed information in daily activities, at home, at work and in the community - to achieve one's goals, and to develop one's knowledge and potential (2002;p. 3).

General Literacy in Ireland

The two most significant studies of Irish literacy have been the OECD's Programme for International Student Assessment (PISA) and the International Adult Literacy Survey (IALS). The PISA assesses 15-year-old students from all members of the OECD countries in prose, documentary and quantitative literacy. In the most recent results for 2000 the only country to outperform Ireland was Finland. The areas of concern: girls substantially outperforming boys and lower performance levels among the lower socio economic groups were common to all countries. The only Irish anomalies were the very low percentage of boys who engage in reading as a hobby and, despite the fact that Ireland had a very good mean score; one in ten has significant literacy difficulties. Ireland was one of the original countries in the IALS finishing a lowly seventeenth of twenty-two. This was central, along with lobbying by NALA and AONTAS, in the appointment of a Minister of State for Adult Education. Denny et al (1999) convincingly argue that the survey did not do justice to Irish literacy standards. The figures were skewed by the lack of access to second level education until the mid 1960s creating 'a cohort effect'.

The OECD statistics (Education at a glance, 2002) show that 31% of those aged between 55 and 64 have completed second- level education compared to 67%of the 25-34 age cohort. Prior to 1966 individuals were obliged to pay fees to attend secondary school. This acted as a

barrier to participation for many. Consequently, the older age cohort has a lower level of educational attainment, which is reflected in a lower level of literacy proficiency. However, the participation rates in education have increased dramatically since the 1970s, which produces a more favourable distribution of literacy scores in the younger cohort in Ireland. The authors effectively demonstrate that the Republic of Ireland, in recent years, has been more efficient in converting years spent at school to literacy levels than the United Kingdom.

Literacy at third level

Literacy within the higher education context is generally thought of in three ways:

1. General competence to express oneself using a standard variety of English suitable to a tertiary level: **Generic Academic Literacy.**
2. The ability to think, speak, read and listen and write well within particular contexts, according to the traditions and usages of particular disciplines: **Discipline Specific Literacy.**
3. The ability to manage and use information effectively: **Information Literacy.**

While the first two conceptions have somewhat different emphases they are interrelated and complementary. The term **Academic Literacy** will be used to encompass both concepts. Academic literacy requires an understanding of the expectations and requirements of a discipline and the development of skills for analysis and communication within that area. Academic disciplines have accepted conventions and methodologies for

1. Text and data acquisition
2. Critical and data analysis
3. Forms of argument and
4. Presentation of communication of information and argument

For a student to meet these expectations they require skills in

1. Critical listening
2. Reading and analysis of text and data and
3. The development of written and spoken skills to develop arguments and the communication of data and text

The development of Academic Literacy needs to be underpinned by traditional or general literacy skills. You cannot have one without the other. The teaching of English is littered with Acronyms: TEFL (Teaching of English as a foreign language): ESL (English as a Second Language): TESOL (Teaching of English to Speakers of Other Languages) and EAP (English

for Academic Purposes). The last is our concern. If a student is academically literate they should be able to engage with discourses appropriate to third level in the areas of thinking, reading, writing and speaking. Additionally they should be aware of the various logical, emotional and personal appeals used in argument and as briefly mentioned above they need skills enabling them to define, summarise, detail, explain, evaluate, compare/contrast and analyse. Ideally an academically literate student has an understanding of audience, tone, language and rhetorical strategies to be successful in various disciplines.

Reading skills

Reading skills can be divided along three axes.

Prose literacy (PL) is the comprehension of written text: editorials, news stories, poems and fiction for example, and is broken down into two types: expository and narrative prose. Expository prose is printed information that defines, describes, or informs, such as newspaper stories or written instructions. Narrative prose tells a story. Prose varies in its length, density, and structure (e.g., use of section headings or topic sentences for paragraphs). Prose literacy tasks include locating all the information requested, integrating information from various parts of a passage of text, and writing new related information.

Document literacy (DL) is the comprehension of short forms or graphically displayed information. These may be real life situations: job applications, payroll forms, transportation schedules, maps, tables and graphs or in an academic context.

Quantitative literacy (QL) is the understanding of information displayed visually, in graphs or charts, or in numerical form using whole numbers, fractions, decimals, percentages or time units. These quantities appeared in both prose and document form. QL involves locating quantities, integrating information from parts of a document, determining and performing the necessary arithmetic operation. Examples are balancing a check book, completing an order form or determining the amount of interest paid on a loan.

Writing

Written work is a fundamental part of third level literacy. It may be used in some format as part of continuous assessment or examinations. These may include essays, business correspondence, synopsises and report writing for example. The skills required to complete these include appropriate expression, structure and grammar. Good academic writing is characterised by suitable levels of formality, objectivity, paraphrasing, synthesis, summation, explicitness, referencing and citation. On a more specific level it should be expected that students could describe objects, define, write instructions, describe processes and

developments, classify and categorise, give examples, compare and contrast, evaluate and analyse.

Information Literacy

Information literacy enables a person to recognise when information is needed and to locate, evaluate and effectively use it. It has dominated the research of third level literacy in recent years. A person considered being information literate is able to

1. Recognise a need for information
2. Determine the extent of information required
3. Access the needed information efficiently
4. Evaluate the information and its sources
5. Incorporate selected information into their knowledge base
6. Use information effectively to accomplish a purpose and
7. Classify, store, manipulate and redraft information collected or generated.

Academic library and information centres throughout the world have been evolving for some time into what is described as the 'hybrid library'. This refers to the merging of the old with the new – the books, journals and physical space of the traditional library combined with the vistas opened up by digital technologies and electronic resources. In the 'library without walls' a user can access high-quality information at the drop of a click either from a library computer, their office desktop, remotely from home or anywhere else. Students have greater choice in how, when and where to access information. In theory it should now be easier than ever to locate and access key learning resources. Without the necessary information-handling skills, however, students are in general ill equipped to exploit this amazing array of resources effectively and productively. Recognising this 'information gap', academic libraries now regard the teaching of information skills as an integral part of their mission.

Current initiatives in Irish third-level institutions

All Irish academic libraries offer a variety of 'user education' programmes to students and staff, ranging from the 'library tour' to more specific workshops on research in the library or using electronic resources. These courses are traditionally stand-alone, generic and often unrelated to specific course work. They are usually not compulsory, assessed or evaluated and are very often not uniform or standard across courses or types of students. Even the most supportive academic staff member finds it difficult to allocate precious curriculum class time to library training. Consequently, librarians are often faced with the prospect of trying to

cover everything from basic research skills to complex search strategies across electronic databases in one annual 60-minute session.

However, some interesting work is being done in several Irish academic institutions. University College Dublin's library, in conjunction with the Student Welfare Service and the professor of psychology, has recently acquired HEA funding to support a research project on the teaching of study skills, information-literacy skills and critical-thinking skills to course tutors and demonstrators in the departments of physics, chemistry and psychology. The project aims to show that this type of intervention helps to retain students. The project team are working with the academic departments to integrate these skills into existing curricula, and the methodology proposed is that tutors would be trained to pass these skills on to their respective students. This is seen as possibly more effective and feasible in terms of staff/student ratios.

In Trinity College Dublin, the library and the department of pharmacology have received funding from the Centre for Learning Technology to develop a programme 'using web-based learning to provide B.Sc. (Pharm.) students with the fundamental skills to solve drug-related case-based problems using optimal search strategies'. The library hopes to use the Medicines Information Retrieval (MIR) project as a template on which to model subject-specific information skills courses applied to other academic disciplines.

In Dublin City University a number of the information courses offered by the library are fully embedded in course curricula, are assessed and accredited. A course entitled 'Effective web searching', for example, is delivered as part of an IT module for 150 first-year science students. The learning outcomes for the course were set by the librarians in collaboration with the module co-ordinator. The assessment relates directly to the outcomes, and accounts for approximately 20% of the overall marks for the module. Another course on library research databases is presented as part of a second-year chemistry module entitled 'Visualization & validation of laboratory data'. This too is assessed and accredited. The library is currently reviewing its courses in collaboration with academic staff in order to identify and agree broader information skills learning outcomes.

Both Information literacy and general literacy are essential to third level success. We will now look at the broader canvas of the Irish system and how it may relate to literacy levels.

Overiew of the Irish third level system

Growth of third level participation

The OECD report on higher education comments that 'the growth in tertiary education in Ireland has been extraordinary with the participation rates rising from 11% in 1965 to an estimated 57% in 2003 and in numbers from about 21,000 in 1965 to over 137,000 by 2003' (Department of Education and Science Ireland).

(type A are degree level course and type B shorter courses leading to a certificate or diploma) are counted together the share of the 25-34 year olds completing tertiary education amounts to 37%, compared to an OECD average of 28%. This is all the more remarkable when the historical context is considered. The completion rate of 14% in the 55 to 64-age cohort compared, for example, to 20% in the United Kingdom while those in the 45 to 64 cohorts had a completion rate of 19% compared to 40% of those in the same cohort in the United Kingdom. By 2002 the corresponding figures were 37% and 31%. It can be extrapolated then that from a position twenty years ago where Ireland had less than half per head of population of that of the United Kingdom attending and achieving tertiary level qualifications it has bypassed it by 6% in 2002. This is a remarkable achievement. It is suggested that Government policy in terms of introducing free education in 1966, the provision of third level places, advantageous demographics and the premium attached to Education in Irish culture have all played their part.

In 2002 36,500 students entered tertiary education through the Central Application Office system of which 90% were in the 17 to 19 age group. The number of full time students rose from 40,616 in 1980 to 123,477 in 2001. The Institutes of Technology accounted for the largest percentage increase. An interesting comparison can be made with the figure of 16,300 who were attending third level in the academic year 1964/5 presented in the landmark publication Report of the Commission on Higher Education (1967).

Table 2. Population that has attained tertiary education (2002)

(Percentage, by age group)

	Tertiary Type B					Tertiary Type A and Advanced Research Programme				
	25-34	35-44	45-54	55-64	25-64	25-34	35-44	45-54	55-64	25-64
Ireland	14	10	7	5	10	23	15	12	9	16
Denmark	6	6	5	4	5	23	24	25	18	23
France	17	12	9	6	12	19	11	10	9	12
Germany	8	11	11	10	10	13	15	14	11	13
Sweden	17	18	14	10	15	22	16	17	16	18
Switzerland	10	10	9	7	9	17	17	16	14	16
United Kingdom	8	9	8	7	8	23	18	18	13	19
United States	9	10	10	7	9	31	29	30	26	29
OECD mean	9	8	7	5	8	19	16	14	11	16
EU mean	10	9	7	6	8	17	14	13	10	14

(Source: OECD EAG 2004 Table A3.3)

Demographics

The proliferation of courses available has provided for a dizzying choice for potential students. Until recent years the demand for all available places was high. This was largely accounted for by demographics. During the 1970s the birth rate was 23 per thousand of population: twice the European average. The HEA forecasts a decline to 13 per thousand by 2016. With the concentration of the entry into tertiary education being predominantly in the 18 to 20 age group (90%), this could lead to a decline in the annual cohort of second level school leavers from around 70,000 in 1990 to around 53,000 by 2015 unless school staying on rates improve considerably. They ambitiously project an increase in the age participation rate to over 66% by 2015. No report to date has mentioned continuing immigration as a possible ameliorating factor.

Entrance standards

Entrance into third level courses for leaving certificate or standard entrants is based on a points system managed by the Central Application Office. Students are allocated points according to the level and grade they achieve in six subjects in the Leaving Certificate examination or one judged equivalent. With the exception of a handful of courses, that may require interviews or portfolios of work, their success is solely dependant on points achieved. While Prestigious courses like medicine, dentistry, veterinary science and physiotherapy have continued a relentless upwards trend there is an increasing trend of stagnation and in many cases reduction of points required in other areas.

It is the Institutes of Technology who largely take the brunt of these reductions. In recent years many courses now take any qualified applicant (AQA) any others have been cancelled or suspended due to lack of interest or suitable applicants. Blanchardstown is in a fortunate position not having experienced any significant downturn up to this point. This can be seen by comparing similar courses at three Institutes of Technology: Blanchardstown, Tallaght and Letterkenny.

The 2004 figures from the CAO office indicate the minimum standards accepted for Leaving Certificate entrants. They clearly demonstrate the significantly higher entry requirements for ITB. For example computing requires 215 points at ITB, 160 at Tallaght while Letterkenny accepted any qualified applicant.

IT Blanchardstown	
BN001 Electronics and Computer Engineering	240
BN002 Computing & Information Technology	215
BN003 Business Studies	280
BN010 Business and Information Technology	225
Institute of Technology Tallaght	
TA002 Computing	160
TA004 Electronic Engineering	AQA
TA102 Business Studies (Bus Admin)	250
TA108 Business Studies - Marketing	270
TA111 Business Studies (Bar Management)	125
TA504 Engineering - Electro/Mechanical Systems	150
Letterkenny Institute of Technology	
LY003 Business Studies	120
LY011 Mechanical Engineering	AQA
LY012 Computing	AQA
LY039 Electronics & Computer Engineering	185

Drop out rates and retention

The issues of drop out rates and retention have been widely debated in recent times. This is a complex area and while beyond the scope of this work the question can be asked if there is a relationship between drop out rates and literacy levels? Failure-rates in the first years of study in the Institute of Technology sector are high and considerably more than in the universities. They are comparatively high at universities: according to an HEA study of 2001 83.2% obtained the degree on the course on which they had initially embarked and the dropout rate from universities seems to be only 10% (Morgan, Flanagan and Kellaghan 2001). One third of students leave without finishing their courses successfully and failure is highest in the first year of study at certificate and diploma level (EDU/EC (2004) 13).

The low levels of children from lower socio economic groups and mature students attending third level are perennial concerns. The connection between these issues and literacy will be explored.

The following points have been made:

1. There has been a substantial increase in provision and take up of third level places in the last thirty years
2. It has become increasingly less difficult for students to obtain a place at third level in many courses particularly at the IOTs.
3. The IOTs have seen the largest percentage increase in participation
4. The inclusion of students from lower socio economic backgrounds has remained a difficult issue to resolve and of those that come from a low SES the majority attend an IOT
5. There is increasing evidence that the standards required for many Institute of Technology courses are dropping although Blanchardstown has not yet suffered the effects of this
6. Retention and drop out rates are an ongoing concern particularly in the institute of technologies
7. Demographic predictions suggest that with the current provision entrance standards will be further lowered until retention and progression rates from secondary schools are improved
8. There is a relatively poor inclusion rate of mature students in the Irish system.

The following questions have been raised;

1. Are the standards required for entrance to some courses too low causing a mismatch between academic ability and course requirements?
2. Do these lowering entrance levels correlate to lowering literacy standards?
3. Are there, then, students on courses whose literacy level is significantly below that required to be successful at third level?
4. Is it the job of Third level educators to address the issue of literacy?
5. If this is the case what is best practice?
6. What can the Institute do to maximise the student's chances of being retained and successful by helping them with their literacy?
7. What are the resource implications?

Assessment of literacy

The problem with assessing literacy is that the core concepts- learning development and knowing-are largely invisible. All we can see is performance on real tasks. What the tasks should be, how complex, how close to real life and how defined are the real challenges of assessment. Resnick and Resnik (1977) we have to be careful of our notion of what it means to be literate. They also point out that we run the risk of imposing elite standards on the population as a whole and stigmatizing those who do not reach our standards. In this case it is relatively straightforward: Do students have a level of literacy that allows them to successfully complete the course of their choice and to subsequently perform effectively in the workplace.

There are three main ways of assessing literacy: self-assessments, surrogate measures and direct measures or tests. The first is self-explanatory and has been used extensively Participants are asked questions in a survey format: How well do you read; very well, quite well, poorly or not at all? It is cheap but tends to overestimate literacy levels. It was assumed for many years that, based on such surveys, the literacy level in the United States was close to 90%. When more accurate diagnostic tests were subsequently used it was found to be closer to 50%. Surrogate, or proxy, measurements could include interviewing teachers or lectures or looking at formal exam results or years spent at school. This is also cheap but is not accurate. Direct testing of an individual's literacy competency is preferable when resources permit.

Literacy can be measured in four domains: Academic knowledge tests and complex task and everyday knowledge tests and complex tasks.

Academic test based knowledge is measured by multiple choice or other tightly structured questions, answered by a single individual within a timeframe and without assistance. All students are assessed on the same knowledge and skills; tests use the same criteria for judgment, while trying to avoid bias. Learners are compared against set standards-criterion referenced - or each other, norm referenced. The U. S. Department of Education notes that a test is standardized if it is based on a systematic sampling of behavior, has data on reliability and validity, is administered and scored according to specific instructions, and is widely used. A standardized test may be norm-referenced or criterion-based. The tests may, but need not, relate to readability levels, grade level equivalencies, or competency-based measurements.

Academic complex knowledge and everyday complex knowledge tasks try to reflect a more holistic view of the individual's abilities. Essays, reports and projects are examples. Both these approaches attempt to measure skills-academic literacy- required to complete tertiary education. They are best carried out and assessed by the same person across the group. Arguably, if done well they are the best measurement of a persons ability to put their literacy and information management skills into practice .

Everyday knowledge tests are competency-based and try to reflect the skills and knowledge required in daily literacy practices. They have been used, sometimes controversially, in the USA for thirty years. The first such- the Adult Performance Level (APL) project- was accused of choosing tasks from the perspective of middle-class whites and for developing a long lists of tasks with no rationale. In addition to bias, tests can decontextualise the practices they seek to measure and treat skills and knowledge mechanistically.

The most developed of the competency-based tests, the **IALS (International Adult Literacy Survey)** strives to avoid both a decontextualised and mechanistic approach. It was the first worldwide study to explore the literacy distributions of adults across twenty two participating countries and provided a common measure to allow comparison of literacy proficiency rather than a mere count of the number of "illiterates" The OECD, the European Union and UNESCO administered it between 1994 and 1996 in association with the individual governments. In 2000, a final report was released (Organization for Economic Co-operation and Development [OECD] 2000,Paris) which stated, "*by 1998, the survey had covered 10.3 percent of the world population and 51.6 percent of the world GDP*" (p.87). The IALS reflects both the strengths and the problems with the test approach. It does acknowledge literacy as a complex set of skills and contextualises it in everyday life. In designing the test items an attempt was made to select real life texts such as bus timetables and advertisements. However, the requirements of psychometric testing for standardisation across twenty-two countries made these texts less like their real-life equivalents. For example, a bus timetable

included in the original test was based on an American model, which was very different to other countries. Notwithstanding, it is the best example of a widely uses and norm referenced standardized competency based approach.

Methodology of the study of firsy year horticulture students at Blanchardstown Institute of Technology

This study attempts to analyse the Literacy levels and Information management skills among first year students at the Institute of Technology Blanchardstown. It seeks to establish a general picture of literacy competencies among Horticulture students and briefly compare the results to the other first year groups within the Department of Informatics and Engineering: Computer Engineering, Computer Science and Mechatronics. Table A shows a breakdown of these groups. These figures represent the number of students who registered at the start of the Academic year 2004/2005. It does not represent the number of students who are on the course now as those figures are difficult to establish. The figures in bold represent the number of students who completed the test. The number of first year computing students who completed the test did not provide a valid sample and were not included.

	Horticulture		**Mechatronics**		**Computer Engineering**	
Students	88	**64**	32	**21**	19	**19**
Male	62	**42**	29	**18**	17	**17**
Female	26	**22**	3	**3**	2	**3**
Standard entry	76	**44**	29	**20**	15	**15**
Mature female	13	**13**	0	**0**	0	**0**
Mature male	9	**7**	3	**1**	4	**4**
Non national male	0	**0**	0	**0**	4	**4**
non national female	**1**	1	0	**0**	0	**0**

The make up of the group is significantly different to other courses in the Department of Informatics and Engineering. The number of mature students in the Horticulture course is significantly higher than any of the others with slighty over 25% in this cohort. For example, less than 10% of the mechatronic students are mature students. In this group there is significant variation: retirees, career changers, second chance and access students. It could be said that the group represents the aspired to demographic spread of all courses in the future. The other significant difference is the gender balance. The female cohort is slightly less than

50%. Mechatronics has slighly less than 10%. In comparison to other courses there is a wide geographical spread. It is evident that this is a diverse group of learners.

The method of testing students was twofold: a non-standardised and norm referenced test set by the author and the production of a written report. While recognising the limitations of these tools they do attempt to measure literacy in the four domaims outlined above. Ideally it would be disirable to use a standardised test but the cost was prohibitive at this stage. The test attempted to measure abilities in grammar, vocabulary, sentence structure and comprehension. Students were allowed an hour and a half to complete it. Grades were awarded in the same way as all work in the college. The test attempted to measure abilities in grammar, vocabulary, sentence structure and comprehension. Students were allowed an hour and a half to complete it. The test was based on the authors experience; ten years teaching second level English in Ireland, Australia and Japan, eight years teaching English as a foreign language and six years lecturing in communications. Grades were awarded in the same way as other exams in the college. The table shows the numbers who took the test in each demographic and the results obtained.

	Horticulture		**Grade A**	**Grade B**	**Grade C**	**Grade D**	**Grade E or lower**
Students	88	**64**	15	19	17	8	5
Male	62	**42**	8	12	10	5	4
Female	26	**22**	7	7	7	3	1
Standard entry	76 *Male 53* *Female 13*	**44** **34** **10**	5 3 2	9 6 3	15 2 7	6 15 0	4 1 0
Mature female	13	**13**	6	5	1	2	0
Mature male	9	**7**	4	1	1	1	0
Non national male	0	**0**	0	0	0	0	0
non national female	1	1	0	1	0	0	0

The results demonstrate that females significanly outperform males. This is particularly pronounced in the standard entry cohort. It should be noted that a significant number of the standard entrants have progressed through the PLC or FETAC, as it is now called, qualification route. Of the 64 students who took the test six students with significant literacy difficulties were isolated. Four were male and two female. Again it is necessary to emphasise

that these students were not screened for specific learning disabilities. The author was made aware of one student who falls into this category. Grade D was recorded for 8 students: 5 male and 3 female. These students would have very basic literary abilities and would struggle to write coherent answers to exam papers. Heretofore this would be a level where students were unlikely to embark on a third level course. The mature cohort is an extremely literate group. Anecdotal evidence points to a large number of this group having held high-powered jobs before entering this course.

A brief comparison can be made with two other first year groups: mechatronics and engineering.

	Mechatronics		**Grade A**	**Grade B**	**Grade C**	**Grade D**	**Grade E or lower**
Students	32	**20**	2	4	4	5	5
Male	29	**18**	2	3	4	5	4
Female	3	**1**	0	1	1	1	0
Standard entry	29	**20**	2	2	4	5	5
Mature female	0	**0**	0	0	0	0	0
Mature male	3	**1**	0	1	0	0	0
Non national male	0	**0**	0	0	0	0	0
non national female	0	**0**	0	0	0	0	0

	Engineering		**Grade A**	**Grade B**	**Grade C**	**Grade D**	**Grade E or lower**
Students	19	**17**	8	4	3	2	0
Male	14	**13**	6	4	1	2	0
Female	4	**4**	3	1	0	0	0
Standard entry	15	**13**	5	4	3	1	
Mature female	0	**0**	0	0	0	0	0
Mature male	3	**4**	4	0	0	0	0
Non national male	4	**4**	4	0	0	0	0
non national female	4	**0**	0	0	0	0	0

The Mechatronics group performed particularly poorly. Perhaps this may be somewhat explained by the sampling or the poor attendance at tutorials. In the tutorials the aspects of grammar tested were extensively practised.

By comparison the Engineering cohort performed very well. There is anecdotal evidence that the mature students in this group had a very motivating effect on this group. There was a palpable sense of competition and earnestness. This was lacking in the Mechatronics group. Attendance was excellent and motivation was high.These qualitative aspects merit further evaluation.

Report writing

It was explained to students three times that that effective writing is a process as well as product. It is not simply a matter of handing in a completed document It should contain drafting and redrafting, seeking advice from Lecturers and peers and attendance at tutorials to perfect these skills. It should seek to analyse and synthesise, to evaluate and sift information and draw on both primary and secondary sources.

The marking scheme was as follows:

Marking scheme for report		
Process	25	
Proposal	10	
Ongoing work	15	
Format/structure	15	
Body of report	50	
Sources used	20	
Evaluation	15	
Synthesis	15	
Use of English	10	
	Total	**100**

Report results

The results of the report followed some of the trends of the test and females outperformed males and mature students were by far the highest achievers. It is a worrying fact that students have even greater difficulties putting together a formal written report. 40% of students showed no ability to engage in the process of writing. Despite the fact that four two-hour tutorials were allocated to research where they could use the Library facilities students were unable or unwilling to engage in Independent learning. We can postulate many reasons why this is so: the human inclination to leave everything to the last minute, laziness or an inability to understand the requirements. It is the author's contention that the continuation of the

terminal examination at second level has a significant role to play. In this regard John Coolahan in his seminal book *Irish Education; History and Structure* (1981) noted that as far back as 1971 the Maduas and Mc Namara report advised the government to include school based tests, oral examinations and other forms of continual assessment in both the Intermediate Certificate (now the Junior Certificate) and Leaving Certificate. Almost thirty-five years later this has not been implemented and the tradition of terminal examinations still survives.

In general students also demonstrated an inability to sift, synthesise, analyse, summarise and apply information sources to the completion of a written document. This lack of Information Literacy is evidenced in an inability to choose an appropriate research topic and to be wholly dependent on the Internet as a source of Information. Despite requests to use books, newspapers, journal articles and so on as secondary sources of information the majority of students see the Internet as the source of all wisdom. In the same vein, despite detailed explanation of the differences between reports and projects many students were unable to provide a report format and despite providing a report title such as The effects of the Internet on Interpersonal relationships on the ITB Campus (with the help of the lecturer) ended up producing a document that was essentially a history of the Internet. This inability to respond appropriately to a title combined with poor sentence structure, spelling, inappropriate and limited vocabulary is indeed cause for concern. It was evident in many reports that a significant amount of the body of the report was taken from the Internet with stylistic and grammatical differences between the introduction and the main body. Evidence points to production of reports essays and other modes of assessment that take the form of a mass of undiffererentiated text culled from the Internet. It was largely the mature student group who realised that books still exist.

The use of primary sources of information was more encouraging. Conscientous students used one or more sources outlined in lectures: interviews, questionnaires, surveys, participant observation and first hand experience. Others were seemed unable to differentiate between real interviews and those available on the Internet. The significant number of young students involved is evidence of a paradigm shift in this regard. Furter research is merited.

Conclusions

General Comments

It is of central importance to stress that this study is preliminary and would need to be followed by an extensive standardised test and further tools of assessment. *These is preliminary results indicate a relatively high level of general literacy difficulties among first year students at the Institution of Technology Blanchardstown.* In the above analysis there is a high variation between class groups. While this is a fact based on the test results and analysisof reed to be considered. The timetabling of particular class groups may have had a slight distortion. This is particularly so in the Mechatronics group where lecture and tutorials were held between four and six and early Friday morning. This had a knock on effect on attendances. Notwithstanding the poorer attendance the results in this particular group were cause for concern. Almost 50% demonstrated poor literacy standards. This stands in stark contrast to the engineering group where there was a much greater level of attendance and achievement. This class demonstrated a much higher level of motivation. The author contends that where there are mature students, who are nearly always highly motivated, to act as role models for the younger students the standards of achievement rise.

Specific conclusions

1. This initial study would point to a problem of literacy among first year students. Overall this figure is in the region of 20%. This figure does not however provide figures for specific learning disabilities and is probably adjustable downwards.

2. The problem is most acute among standard entry male students. Across all class cohorts their mean scores were lowest in both the test and report writing. Oral presentation was the only area where their scores were comparable to other groups.

3. Literacy levels are highest in the mature entry female cohort. The standard is slightly lower among the male mature entry cohort.

4. Non-national students have different problems unique to their native language. These include inversion, verb tenses, usage of definite and indefinite articles and prepositions. However 50% show a good standard of literacy.

5. A significant minority of younger students are unwilling or unable to engage in independent learning.

6. There is an overwhelming dependence on the Internet as a source of information. This is exclusively a problem with younger students.

Recommendations

1. **Pre-entry literacy and learning difficulties screening for mature students and early screening for CAO students**

   There is an increasing case for pre- entry literacy testing given the increasingly diverse pathways of entry. Current practise does not allow for this with leaving certificate standard entry students as their success is ringfenced by the points system administered by the Central Application Office and the minimum entry standards specified by the individual institution. However this is not the case with non-standard applicants. It is recommended that all applicants that fall into this category be given a comprehensive qualifying literacy test. The precise structure of this method needs to be worked out collaboratively. The author recommends that it includes a standardised literacy test and an oral interview. The Literacy working group should, in collaboration with interested stakeholders establish a comprehensive set of assessment tools. Under this rubric may fall APELS, portfolios of work, qualitative assessment of literacy whereby they write an essay, for example, in controlled circumstances. Should they not have the standard required they should be redirectered elsewhere until their standard is proficient. This should apply to all courses including the foundation certificate as it now stands. The author recognised functional illiteracy in tweo candidates who had been accepted on this course in the academic year 2001/2002. These students had difficulty from the start and subsequently dropped out. It was suggested to the team that pre entry literacy tests be put in place the following year. This was done and those with profound difficulties were recognised and redirected. It is extremely doubtful if the foundation course can help these students achieve their desired learning outcomes without an intensive programme of one to one tuition as outlined below. It is recommended that the Foundation team liase with the NALA and ideally have one of their tutors on the interview panel. In the case of direct entry students screening should occur quickly after entry. This would allow appropriate structures and supports to be put in place early in the Academic year and maximise the potential of the students.

2. **Standardisation of entry standards for mature students across the sector.** This is in line with recommendation number 49 of the points system commission. The co-ordination of a nationally recognised and transparent procedure for assessment of mature student applications, providing for flexible entry routes taking into consideration the needs of

non-traditional higher education applicants, including APEL, portfolio presentation interviews, the needs of students with disabilities etc.

3. **The provision of units of study for credit which students who are deemed to be at risk must take as a prerequisite in first year courses in addition to the current provision.** This could take the form of bridging courses at the start of the first semester for those identified as weak, which would allow all students to start on a relatively similar footing. These would need to be a minumum of two weeks duration. This practice is currently being used for the computer appications section of the module in horticulture entitled Communications and computer applications. This is in line with recommendation number ten from the Report on the Points system which states that access programmes be geared to the needs of the individual student in terms of content, duration (e.g., summer, late autumn or year-long) and provider, based on the following categories: First category – students who achieve just over three hundred points With this level of attainment course options are very limited and exclusion stems from rationing rather than the individuals abilities. Students in this category could be catered for through a system of reserved places with direct entry. This would off set the competitive disadvantage of such students. Second category – students who achieve only minimum matriculation requirements (2 grade Cs and 3 passes) Students in this category are at high risk if they enter without further preparation. These students need a pre-entry preparatory programme as well as reserved places with direct entry. Supports post-entry would not be sufficient. Third category – Students in this category would not have attained minimum matriculation requirement for access to higher education. Such students are the least supported and face very few options. Bridging courses must be a major part of the strategy.

   It is recommend that the institute consider running a **pilot course** in line with recommendation number eleven of the commission which states that recommends that the National Office should encourage higher education institutions to set up new types of access courses, of varying content and duration, on a pilot basis. One such development would be to have pilot regional consortia of institutions providing intensive Summer Schools (both top-up and orientation) to targeted students. The report highlights one such scheme. The University of Dundee offers a substantial academic 'top up' delivered in an intensive three - month period (June to August). Students are given an intensive programme (9-5 every day), covering study skills together with academic courses that are assessed by course work and examination. Dundee has the statistical evidence to demonstrate that students progressing from this course do as well subsequently as those

entering through the more conventional routes, including those studying in Law, Medicine and Engineering (for a description of the Dundee system see CVCP (1998)).

4. **One to one classes for those particularly at risk**

   This is the ideal form of literacy tuition. Literacy is closely bound to self-esteem. It is a private issue and can have profound implications for the individual. Providing one to one tuition affords the individual privacy and help confidence and trust to grow. It is obvious that this is an expensive option

5. **The provision of discipline specific and course specific instruction into curricula in addition to current modules.**

   For example, Engineering students would be required to take a module in Technical Communication. This would potentially allow for content knowledge and relevant skills at the same time. It would have the added advantage of equitability, as no student would be singled out as needing remedial instruction. The underpinning philosophy in this approach is that all students need to develop their literacy skills pertaining to the specific discipline that they are studying. For example, focussing on effective, efficient and critical reading skills would enable a better understanding of the content information that is being conveyed in a text entitled *The basics of Electronic Engineering*.

6. **The provision of classes and workshops** on literacy skills outside the formal curriculum, which would seek to provide interested students with context free literacy instruction It is proposed that such classes would put the emphasis on literacy as opposed to study skills.In the specific case of the foundation course where the majority of the participants are likely to have less formal education it is vital to maximise literacy levels if they are to make the transition to undergraduate courses. If it is the policy to accept allcomers it is of central importance that they receive extensive literacy tuition.

7. **A greater emphasis on Information Literacy.**

   Institutes should recognise the importance of information-literacy as a key component of academic success, containing a necessary set of transferable skills for life-long learning in the information age. To this end, the concept of the information literate-graduate should be formally integrated into teaching and learning development strategy. Academic libraries should carry out the necessary research to evaluate the resourcing and implementation of information-literacy programmes across undergraduate and post-graduate courses. From this research should emerge a clearly defined implementation plan.. Costs should be evaluated and the necessary funding identified. Information literacy courses should be an integral part of all new course design. Librarians should be included

in course boards and course-design teams. Skills mapping techniques should be used to identify the level of student competencies in information literacy skills as a basis for course design. In the short term, faculties should recognise the need to allocate curriculum time to library programmes. Academic and library staff should collaborate to ensure that the programmes on offer are course-related and relevant to immediate student need.

8. Staff assistance

It is recognised that lecturers within a specific discipline may not have the expertise to embed literacy skills in their specific area. Many would view it as outside their remit and this may be accepted as a valid position. Appropriate staff development opportunities should be provided for those who wish to become more knowledgeable in this area.

9. Redrafting of the current communication modules

The author is responsible for delivering a number of modules to first year students. Having completed this study deficiencies in the syllabi have been recognised and will be remediated under the upcoming Programmatic review. These changes are outlined below. The author contends that the provision for communications is adequate only in the case of the Computing course (BN002).This cohort have a compulsory modules in *Personal Development* in the first semester and *Communications* in the second semester. This provision is an excellent chance to develop literacy skills. All other courses lag significantly behind. In Horticulture (BN007/8) and Engineering (BN002) students take a half module in communications. However it is unsatisfactory in the Mechatronics course where the module is entitled *Personal Development*, which is offputting, and covers material that would be more appropriately dealt with in workshop format by an acknowledged expert. The module title could be changed to, for example, *Communications and Information studies*. This would arguably appear more interesting to students. It is the authors intention to make changes in the upcoming programmatic review. It is suggested that the library have an input into designing the new syllabus.

10. Involvement of external bodies dealing with literacy.

There is a wealth of resources and information available from designated bodied like NALA and AONTAS. Linkages should be developed between these the Institute and these bodies to develop appropriate supports.

11. Reevaluation of Leaving Certificate English requirements.

Current leaving certificate students do not have to achieve a level in English above grade D at ordinary level. This does not represent a sufficient level of competency as indicated

by the IALS to embark on a third level course. It is recommended that the management review this issue and consider one or more of the following options:

(a) Raise the minimum grade required in English to a C at ordinary level.

(b) Offer those with a grade D an opportunity to take the two standardised tests outlined above to ascertain their literacy level.

Or

(c) Make it compulsory for those identified at risk to take one of the modules outlined.

12. **Literacy profiles**

Gaining a literacy profile of a student cohort assists in both targeting those who are at risk and formulating stratagies, which aim to meet their needs and those of the entire group The measures outlined should be used to gain an effective profile.

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Notes;

1. **Dyslexia** causes difficulties in learning to read, write and spell. Short-term memory, mathematics, concentration, personal organisation and sequencing may also be affected. Dyslexia usually arises from a weakness in the processing of language-based information. Biological in origin, it tends to run in families, but environmental factors also contribute. Dyslexia can occur at any level of intellectual ability. It is not the result of poor motivation, emotional disturbance, sensory impairment or lack of opportunities, but it may occur alongside any of these. Skilled specialist teaching and the use of compensatory strategies can largely overcome the effects of dyslexia.

2. **Dyspraxia** is an impairment or immaturity of the organisation of movement. It is an immaturity in the way that the brain processes information, which results in messages not being properly or fully transmitted. The term Dyspraxia comes from the word praxis, which means 'doing, acting'. Dyspraxia affects the planning of what to do and how to do it. It is associated with problems of perception, language and thought. Dyspraxia is thought to affect up to ten per cent of the population and up to two per cent severely. Males are four times more likely to be affected than females. Dyspraxia sometimes runs in families. Other names for dyspraxia include Developmental Co-ordination Disorder (DCD), Perceptuo-Motor Dysfunction, and Motor Learning Difficulties. It used to be known as Minimal Brain Damage and Clumsy Child Syndrome.

3. **Post Leaving Certificate Courses**
   The Post-Leaving Certificate programme, or Vocational Preparation and Training Programme, was introduced in 1985 to provide appropriate vocational training for young people to bridge the gap between school and work. The programme integrates training for vocational skills in particular disciplines, and the development of general skills necessary in all jobs such as interpersonal skills, adaptability and initiative. It also provides for work experience to give relevance to the skills learned and an appreciation of working life. Post Leaving Certificate courses are full-time, of one and two years duration, and offer integrated general education, vocational training and work experience for those who need further training to enhance their chances of gaining employment. They now fall under the remit of FETAC.

4. **NALA**
   The National Adult Literacy Agency (NALA) was established in 1980 and since 1985 it has received a grant to operate a national office. NALA is a membership organisation with voluntary status, concerned with national co-ordination, training and policy development in adult literacy work in Ireland.

Lexicon and Grammar

Dr. Anna Herwig
Trinity College Dublin

Abstract

Over the past decades it has become generally acknowledged that lexicon and grammar are inseparably linked, constituting "a continuum of symbolic structures" (Langacker 1990:2). Yet, a comprehensive integration of the two realms of knowledge appears to be a difficult task. The present article offers a unified psycholinguistic perspective, which is centred on the mental lexicon, considering grammatical knowledge as part of the information structure of lexical items. It aims to model the complexity of lexical knowledge such that its perceived psychological reality, including various levels of linguistic description, becomes discernible.

1. Lexical Information Structure[1]

In the light of recent research undertaken in different linguistics fields (cf., e.g., Bybee 1988, Ellis 1997, Langacker 1990, Singleton 1999), the mental lexicon can be described as that domain of language where the various dimensions of linguistic information meet. A comprehensive description of lexical knowledge must therefore take account not only of formal and semantic but also of grammatical knowledge. It follows that the elements of the lexicon need to be modelled as highly complex entities, including information on representational substance (conceptual, perceptual, and articulatory patterns) and combinatorial potential. Combinatorial knowledge relates to an item's collocation and colligation, i.e., its valency structure (cf., e.g., Langacker 1987, Lutjeharms 1994, Singleton 1999). It has various facets and is relevant for phrasal construction. Combinatorial knowledge is associated with specific types of semantic and formal relations, which reflect the distributional properties of lexical elements (cf., e.g., Bybee 1988, Ellis 1997).

The different knowledge components are mutually dependent and interact in our use of language. I will aim to integrate representational substance and combinatorial potential of lexical items in an all-embracing psycholinguistic component structure model, which coordinates the different levels of description. The model provides a framework for discussing grammatical processing with reference to lexical knowledge. It also draws a unified picture of lexical items, which provides the grounds for illustrating the perceived psychological reality of lexical networks.

[1] For a more differentiated discussion of lexical information structure and applications of the proposed model cf. Herwig 1994.

2. Lexical Items as Mental Models

In order to illustrate how the various dimensions and aspects of linguistic knowledge merge in the information structure of lexical items, I suggest that words should be viewed as mental models, similar to conceptual frames employed by cognitive semantics to describe conceptual structure (cf., e.g., Barsalou 1992, Lakoff/Johnson 1999, Minsky 1975, Mervis/Rosch 1981). Following Cohen (1990:316), mental models are defined as extended conceptual frames, "consist[ing] of constructed groups of concepts which constitute the generic knowledge about events, scenarios, actions, or objects … [and of] relations together with slots, or variables, which can be filled with optional values". Lexical information structure can be compared to that of complex cognitive events like scenarios etc., and the organizational structure of mental models appears to be tailor-made for explaining the complexity of lexical knowledge. I will therefore describe a lexical (semantic[2]) item in terms of a multidimensional knowledge unit in the form of a conceptual frame consisting of a number of interrelated and dynamically interacting domains of knowledge. It illustrates grammatical knowledge by elucidating lexical valency and dependency structures and renders possible a comprehensive psycholinguistic perspective on lexical organization and processing. This is considered useful for explaining the principles of phrasal construction and for elucidating the foundations of production errors.

Figure 1 displays the dimensions of lexical knowledge as a set of seven attributes, five of which, *semantic quality*, *semantic and syntactic valency*, and *phonological and (ortho)graphic layout*, relate to intellectual aspects, the remaining two (*pronunciation structure* and *written output structure*) to motor patterns. These latter are connected to their respective domains of formal knowledge and are primarily relevant for language production, while the other dimensions are essential for all situations of language use. Motor knowledge will not be discussed any further here.

[2] The following model is primarily designed to illustrate the information structure of *semantic* items. It may therefore not be entirely suitable to represent *grammatical* items, in particular their semantic structure.

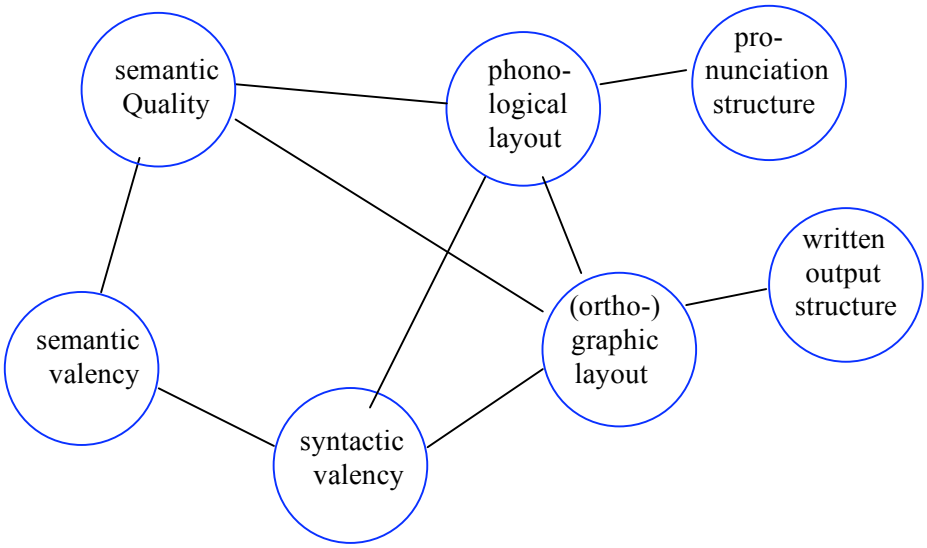

Figure 1 Lexical information structure: frame of attributes

Semantic quality, semantic and syntactic valency, and phonological and orthographic layout are regarded as the central attributes of lexical knowledge, which set the outline conditions for language use. These attributes, which corresepond to specific dimensions of knowledge, are particularised for a range of values, some of which are further differentiable.

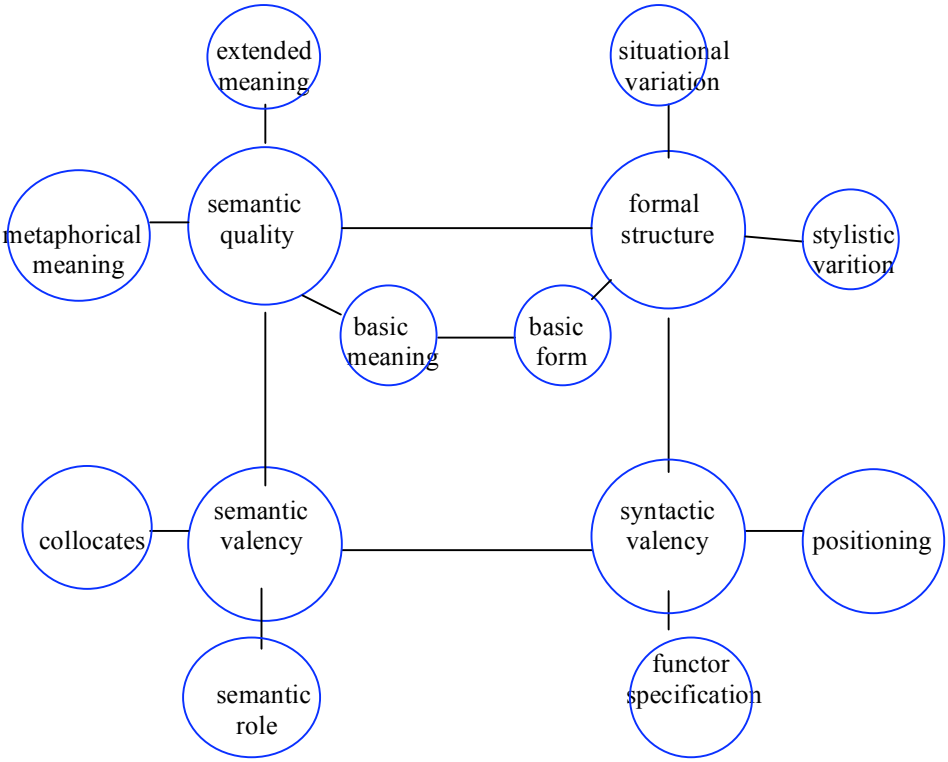

Figure 2 Lexical information structure: detailed Frame Model

Figure 2 illustrates a selection of values associated with the different attributes. Each of them is seen as being individually pronounced for a specific lexical item. Phonological and orthographic knowledge have, for the sake of simplicity, been subsumed under the heading of *formal structure.* The correlation of these attributes is highly variable, and even in alphabetical systems the degree of correspondence between sounds and letters can vary considerably.

We are now left with a frame consisting of four attribute-value sets, four dimensions of lexical knowledge, which interact in putting lexical items to use. They are part of an individual item's information structure, but their impact extends beyond the word level. Before discussing their dynamic relation, I will outline the function of the attribute-value sets. They are seen as representing the following knowledge structures:

Semantic quality relates to aspects of meaning, comprising a *basic meaning*, context-dependent *modified* or *extended* shades of this meaning, and *metaphorical* meanings.

Semantic valency refers to meaning-related combinatorial aspects, which include the range of associative connections with other semantic items (*collocates*), and to an item's semantic role within such configurations. In other words, the attribute specifies the way lexical items are connected on the basis of their conceptual content. It covers, on the one hand, concrete information about possible alliances, as emerging from an item's conceptual frame. ***Collocates*** relate to different types of associations with other semantic items, which can be distinguished as being either *natural, conventional, personal,* or *situational*. Semantic valency is further seen as including semantico-grammatical information about an item's semantic role in a complex setting. It refers to the relational status or function of an entity in a given scene. Semantic role thus relates to the notion of syntactic category as the grammatical specification of the semantic status of lexical items.

Closely associated with semantic valency is ***syntactic valency***. It relates to aspects of formal representation, namely to the arrangement of lexical forms as reflective of the relations that hold between their conceptual contents. It thus refers to *grammatical* or *morpho-syntactic adaptations*, in particular to *functor specification* and to the determination of an item's position in phrase and sentence (*positioning*). The interdependence and interaction of semantic and syntactic valency will be discussed in more detail later.

The remaining attribute-value set (*formal structure*) relates to lexical-formal knowledge. It includes a *basic form*, and information on possible *situational* or *stylistic variations*, as, for example, allophonic variation in spoken language.

I will now take a closer look at the relations within the lexical frame, and at the interdependence of the different attributes and their values.

To begin with, the given quadrangle can be sectioned in two ways:

1. The two dimensions on the left relate to aspects of conceptual-semantic structure, those on the right to their formal linguistic representation. This division singles out the complementary poles of a symbolic structure.
2. The upper two attributes relate to an items representational substance, the lower two to its contextual behaviour.

The most fundamental relation within the lexical frame holds between *basic meaning* and *basic form*. Basic form relates to a non-inflected form; basic meaning is used to refer to its most readily associated conceptual content, which may vary across individuals but often relates to central category members (e.g., the lexical form 'horse' is usually associated with a prototypical horse as opposed to its wider meaning which would include Shetland ponies and other more peripheral members). This primary word knowledge could be considered the *core entry* of the mental lexicon and might be compared to the basic entry in a dictionary.

Semantic quality and semantic valency structure are seen as being mutually dependent. The precise meaning of an item emerges from its contextual embedding, i.e., its collocational environment (e.g., the meaning of horse in the context of riding is different from that in the context of handicraft). Conversely, a specific meaning can put restraints on the collocations an item can enter into. An item's status or function relative to its collocates is situationally specified. It finds its formal expression in morpho-syntactic modifications, which are associated with syntactic valency structure (e.g., whether the mouse is afraid of the elephant or *vice versa* determines their sentence position and inflectional adaptations (if applicable)).

Semantic and syntactic valency provide the outline framework for an item's integration in larger contexts, i.e., for combining lexical items into meaningful stretches of language. As such, their combined information can be regarded as the main body of grammatical knowledge. Morpho-syntactic information is also related to an item's formal structure. The latter determines the shape that morphological modifications will take (e.g., type of plural suffix). Conversely, morpho-syntactic specifications can give rise to formal adaptations (e.g., shift of stress pattern).

Following this outline of the suggested dependencies within the lexical frame, I will proceed with a closer look at the information structure of semantic and syntactic valency and give a basic outline of their interrelation.

Semantic valency is defined as the information about an item's combinatorial potential at the conceptual level, which is formally expressed in its syntactic valency (Lutjeharms 1994:150). It relates to two aspects of collocational information; to possible co-occurring elements and to the item's possible positions in relation to these elements. An item's relational status, i.e., its position or function relative to other items, is referred to as *semantic role*, and it is seen as being conventionally associated with morpho-syntactic specifications to express this role. This means that, for nouns, for example, their thematic role is linked with certain grammatical modifications (as associated with syntactic category), which involve determination of sentence position, inflection, or use of prepositions, as appropriate. Verbs would be identified as to their specific predication in relation to their arguments and adapted accordingly (inflection according to person, number, tense, aspect, etc.). Beyond that, they have an influence on the grammatical behaviour of other words. The valency, or argument structure of relational items, in particular verbs and other predicative elements, includes information about required modifications of their collocates in a given context. They can determine grammatical structures (as, for example, infinitive or gerund constructions) and morpho-syntactic modifications of their arguments (such as word order or case structure in many languages, or the use of prepositions). The syntactic valency of predicative items can thus be described as having an *internal* dimension, relating to their own grammatical behaviour, and an *external* one, relating to modifications of other elements. Also of importance is the fact that predicative items are seen as linking up grammatical items, i.e., that these are regarded as part of their information structure.

In sum, the valency structure of lexical items is seen as holding the main body of grammatical information. This supports the view that the separation of lexicon and grammar is an artificial distinction, and that language production springs from lexical knowledge, rather than from a pre-lexical grammatical scaffolding to be filled out with words, as has been suggested by the Chomskyan tradition. The grammatical scaffolding of a phrase or sentence arises from the information structure of the lexical items used and is specified on the basis of situational conditions.

3. Phrasal Construction

Utterance formulation can be defined as the selection and meaningful arrangement of lexical items. Different schools of thought distinguish different procedural mechanisms, sometimes involving rule-based grammatical operations that appear to be complex beyond cognitive reality (cf. Herwig 1994:66ff). A useful delineation is provided by Aitchison's (1989) model of sentence planning, which posits two major processing stages, labelled as *outline planning* and *detailed planning*. They are seen as relating to the selection of certain key words

(semantic items) and the syntactic structures they determine, and to the activation and arrangement of supplementary elements. Aitchison's perspective can be set in relation to Garrett's (e.g., 1988) model, which distinguishes two classes of processing systems, lexical selection and phrasal construction. Phrasal construction includes the syntactic specifications assigned to Aitchison's outline planning and the operations involved in her account of detailed planning.

I will now discuss the mechanisms of phrasal construction in the light of lexical information structure. They are seen as involving the interaction and interdependence of different knowledge components and operational mechanisms. It needs to be emphasised that phrasal construction is here not seen as a distinct processing phase, but as a description of the kind of operations traditionally associated with grammatical processing. These mechanisms and their underlying organisational principles can be elucidated with reference to the above frame model.

The semantic items selected to represent a given conceptual event are here considered to contain, by virtue of their component properties, all the information required to express this concept in a complex phrase or sentence. The specific configuration of the conceptual scenery, i.e., the nature and relational status of its component parts, determines the semantic role of their referring expressions and is seen as initiating morpho-syntactic specifications. These include their sequential activation and morphological modification and the triggering of function words. This operation is likely to involve two processing steps, because morphological adaptations and the use of grammatical words depend on the nature and arrangement of the selected content words (cf. *Peter's book* versus *the book of Peter*, where the serial order of *Peter* and *book* determines the use of different functors). Perhaps more important to emphasise, however, is the fact that phrasal construction is here seen as involving the parallel and interactive processing of the different dimensions of knowledge of all the selected semantic items. The resulting phrase or sentence structure is then posited to be a product of the joint information of the different items involved.

Much of the process of phrasal construction can be related to the retrieval of flexible formulaic sequences. Such prefabricated linguistic patterns determine a specific grammatical construction and provide slots for certain groups of lexical items (cf., e.g., Perkins/Wray 2000). The most fundamental formulaic sequences are seen in this perspective as being governed by the valency structure of predicative items. These determine the grammatical construction they appear in, as well as the morpho-syntactic specification of obligatory and possible arguments. Carrying the main body of information about sentence structure, predicative items are regarded on this view as the key items of phrasal construction. Their

function is to specify the relation that holds between certain events, not only by virtue of their meaning, but also by providing a structural framework for verbalising this relation. This framework offers a range of possibilities, which are situationally realised depending on the nature of the arguments and on the perspective taken on a given scene. An example may serve to illustrate these explanations:

The inner state of fear can be expressed by the adjective *afraid* or by the verb *fear*. Both items require two arguments, an experiencer and a cause. *Fear* determines that the experiencer has to be in the subject position and the cause in the object position. The latter can take the shape of a thing or an action. *Afraid* also requires a form of *be* to link up inner state and experiencer, and the preposition *of* to link up the cause. It then offers two possibilities: if the cause is a thing, a noun can be slotted in; in the case of an action, a gerund is required. Let us assume Peter cannot swim. The situation provides experiencer (Peter), relation (fear), and cause (water or swimming). If the item *afraid* is selected to express Peter's fear, it automatically triggers the linking functors and determines the sequential arrangement of the different elements. The realisation of *be* as *is*, additionally depends on the fact that the experiencer is a single person, and on the speaker/writer's present viewpoint. We thus arrive at one of the following utterances:

- *Peter is afraid of water*
- *Peter is afraid of swimming*

A selection of the verb *fear* to verbalise Peter's feeling would have resulted in one of the formulations:

- *Peter fears water*
- *Peter fears swimming*

Here, the syntactic valency of the predicate does not specify any linking elements to express the interrelation of the different semantic items.

The proposed mechanism of phrasal construction as outlined here suggests that the semantic items selected to express a given conceptual configuration immediately and interactively trigger the grammatical items consistent with them. This hypothesis bears important implications for the organization of grammatical items (cf., e.g., Bates/MacWhinney 1989, Green 1993). Elements with a mere grammatical function, such as many bound morphemes or semantically empty words like postpositions, could be bound up in the lexical network primarily on the basis of formal connections to semantic items. Their selection may – at least in many instances – depend entirely on the semantic items they modify, and they may not

have in such instance an independent semantic quality. An investigation of the processing of grammatical items could shed further light on this question.

4. Multidimensional Connectivity of Lexical Items

Lexical connectivity relates to semantic and formal associations of different types. At the conceptual level, an item is linked to semantically related items, at the formal level to formally similar or grammatically associated items. This complexity is traditionally described with reference to different types of lexical networks (cf., e.g., Aitchison 1994). In order to illustrate the perceived psychological reality of lexical connectivity, it would be useful to integrate the different levels of description in a single comprehensive network model.

An integrative network model needs to portray the diversity of associations that hold between words, distinguishing different types of semantic and formal connections. In order to be transparent and psychologically realistic, such a model has to portray lexical items as unified cognitive entities. The lexical information structure model provides an integrative perspective on lexical items, which satisfies these demands. It could be used to represent words in single-level networks. It could, however, be slightly confusing in a graphic illustration, if each item were represented by its lexical frame. An alternative display, which renders a network model more transparent, would be to illustrate the component properties of lexical knowledge as a set of layers centred around the semantic quality as their core attribute (cf. figure 3).

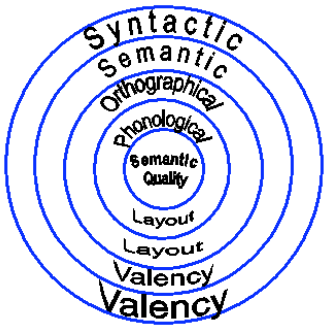

Figure 3 Lexical information structure: Layer Model

This display has the additional advantage of being able to rank the relative significance of the attributes in descending order from centre to periphery. The two inner circles, semantic quality and formal structure, can be said to constitute the 'hardware' of lexical knowledge, the linguistic sign. This portrayal is seen as representing the character of a lexical item particularly well: a conceptual content is encapsulated in a linguistic form. It shows the inseparability of the two dimensions; a form without a meaning would be an empty cover, a non-word, while a conceptual content without a formal frame would be a non-lexicalised

concept. The two outer layers, then, represent the item's combinatorial potential: information about putting lexical items to use, or 'lexical software'. Again, the semantic component is contained in, i.e., expressed through a formal shape.

The specific nature of the relations that hold between words in a comprehensive network could now be illustrated as associative connections at different levels of description, by linking the respective attribute layers. In this way, the specific character of the relationship of an item like horse to semantically or formally related items (e.g., pony, foal, or hoarse, house, respectively) and to collocationally or colligationally associated ones (e.g., stable, riding, or a, the, and an inflectional suffix like plural –s, respectively) can be integrated in a relatively transparent way. A further advantage of this approach is that multiple connections between lexical items become visible. Associations at several linguistic levels, as opposed to single connections only, could be regarded as a factor of strength of lexical links.

The above manner of illustrating lexical connectivity is thus seen as being useful for both making visible and disentangling the confusing complexity of lexical networks. Perhaps most importantly, it helps define an item's specific position in the lexical network.

5. Conclusion

The proposed frame model depicting the information structure of lexical items, and its underlying perspective on lexical information structure, has been shown useful for different purposes. It elucidates the interrelation of lexical and grammatical knowledge, providing a comprehensive and psychologically realistic view of the various dimensions of linguistic knowledge merging. This integrative view renders a description of the mechanisms involved in grammatical processing and phrasal construction more transparent, and can also be used for detecting the foundations of production errors. It has further been found suitable to provide a framework for illustrating the multidimensional structure of lexical networks.

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