Phase Focus

10 December 2010

TAKE A CLOSER LOOK

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Phase Focus is commercialising a disruptive lensless imaging technology (the Phase Focus Virtual Lens®) which uses a proprietary mathematical algorithm to generate microscopic images from the diffraction pattern generated by an illuminated beam on transmission through or reflection from a specimen.

Applicable to the full electromagnetic spectrum as well as to electron and other particle waves, the Virtual Lens has demonstrated significant potential in a broad range of applications spanning from cellular assays and semiconductor metrology to X-ray synchrotron microscopy.

In the course of this note we shall illustrate that:

- The Virtual Lens technology eliminates the need for lenses
- It also enables content-rich, quantitative, and aberration-free microscopy
- It can be incorporated within existing instruments, or can be used in stand-alone product configurations
- There are competitively-differentiated applications in multiple markets
- The Group possesses an extensive IP portfolio
- Phase Focus has already built strong OEM relationships in a targeted number of specialist applications in global markets of scale up to US$ multi-billion.
- Given the high margin nature of the business and the requirement for low capital expenditure, the current funding round (seeking £1.25m) is likely to be the last opportunity to participate in Phase Focus prior to exit.

Encouragingly, our forecasts show the group moving into profit as soon as 2012. A discounted cash flow analysis on projected revenues in coming years yields a fair value on the business of £11m (pre new monies, and with a highly conservative discount rate of 33%).

However, we prefer to adopt even more stringent consideration of the challenges facing young growth companies in the current economic climate and attach a fair market value of half that amount, £5.5m, which should move towards the DCF mark on execution of strategy and tangible commercial progress.

Forecasts

Year to 31 May, £m	2011E	2012E	2013E	2014E	2015E
Total revenues	0.49	1.55	3.55	9.20	20.28
Profit before Tax	-0.42	0.02	1.00	3.77	10.51

ED estimates

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INTRODUCTION

Phase Focus has developed a method for imaging and microscopy that transfers the task of image formation from physical components (lenses) to a software algorithm.

Founded in June 2006, Phase Focus is a subsidiary company of AIM-listed Fusion IP plc ("Fusion IP"), which owns 54% of Phase Focus and also the rights to 100% of university-owned research generated at two UK universities – The University of Sheffield and Cardiff University. Phase Focus was launched by Fusion IP (then BioFusion plc) in 2006, which made an initial investment of £200,000 to provide for further development and validation of its proprietary technology. Dr Ian Pykett, an experienced manager of technology companies, was appointed as CEO to Phase Focus in the same year.

Phase Focus is a spin-out from the University of Sheffield, exploiting the potential of the Virtual Lens. Professor John Rodenburg of Sheffield University, a founder of Phase Focus, created the process that can generate high definition images of an object without the need for the high quality lenses. Thus the Virtual Lens eliminates the need for costly high-quality lenses in high-performance microscopes by using a computer algorithm to image the specimen from the pattern of scattered light (diffraction pattern) as it transmits or reflects the light waves.

This disruptive technology eliminates the limitations of conventional focusing devices — across the electromagnetic spectrum from optical to X-ray photons, and also for electron waves — and enables a number of significant new capabilities including post-acquisition focusing and high-contrast stain-free imaging. The Virtual Lens can also be incorporated into existing imaging equipment, offering performance enhancement and new capabilities at relatively low cost.

Virtual Lens TruWave™ images are content-rich and quantitative, and the technology has already established strong interest in several applications which can exploit this disruptive technology immediately.

Technological Applications

Wavelength spectrum	Market	Application	Est global market size, US$bn
Optical	Semiconductor metrology	Overlay, film thickness, critical dimension metrology	2.1
Optical	Cellular assays	Automated analysis of proliferation, cell loss, motility and division	0.7
Optical	Contact lens	Measurements in natural hydrated state	5.3
Optical	R&D microscopy	Stain-free live cell microscopy	0.7
Electron	R&D microscopy	Ultra-high resolution and TEM-on SEM "two-in-one" instrument	1.5
X-ray	X-ray synchrotron microscopy	Analysis of quasi-crystalline proteins (eg collagen)	0.2

Source: Company, ED

In November 2010, the key terms of a royalty agreement were agreed with a major electron microscopy industry player that has worked with Phase Focus to test the Phase Focus Virtual Lens technology, and successfully demonstrated its operation in a commercial electron microscope.

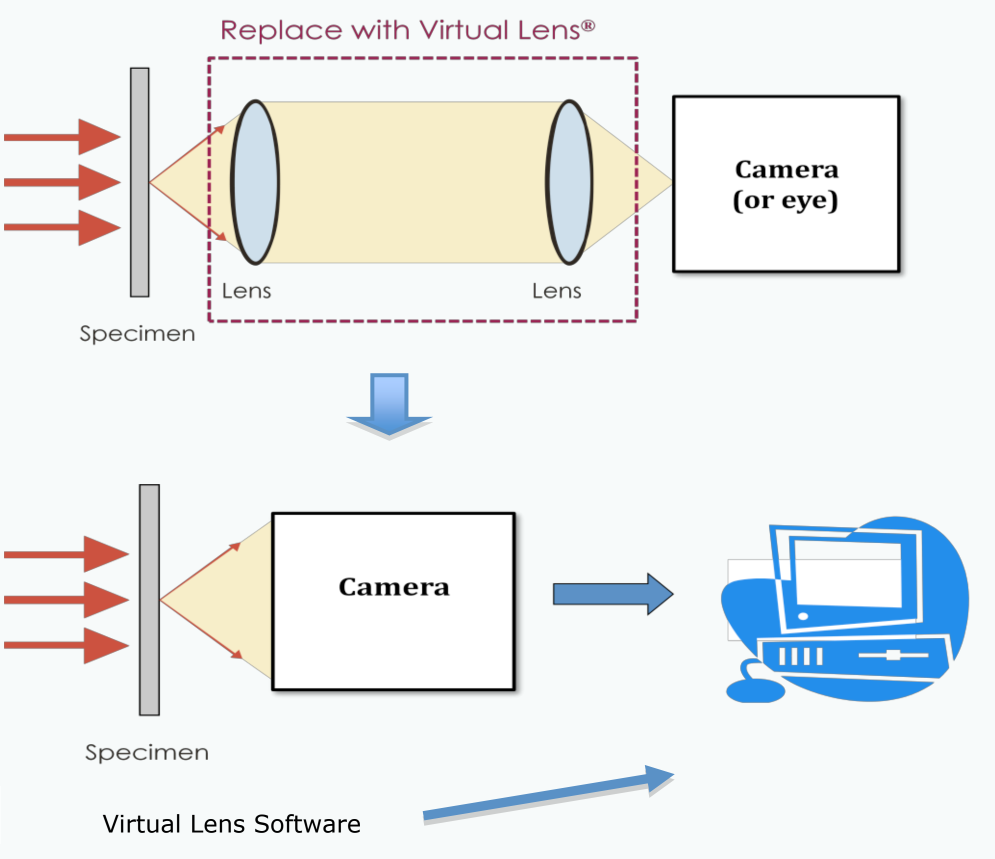
TECHNOLOGY

Introduction

Optical microscopy is perhaps the most familiar form of microscopy, and has been of immense value in many fields of research over several centuries. It reaches a physical limit when feature sizes fall below 0.5 microns (500 nanometres), and as it approaches this high level of performance, the cost of lenses typically rises to between £15k and £20k.

In the conventional "brightfield" microscope, light from an incandescent source passes through a condenser lens which concentrates the light on the specimen under investigation. The light passing through the specimen is focused by the objective lens before passing through a second magnifying lens, the ocular or eyepiece en route to the observer's eye. As shown in the diagram below, Phase Focus replaces the optical lens system with its Virtual Lens.

Virtual Lens



Company

When dealing with living organisms or transparent specimens, unless these are stained, the images from a conventional microscope suffer low contrast and appear featureless:

The problem lies in the insensitivity of the human eye, and indeed electronic detectors like CCDs and CMOS devices, to any phase changes in the light waves brought about by differences in the thickness and refractive index between the specimen and its surrounding medium. The conventional solution is to stain the specimen with coloured dyes, but this process can kill or alter the specimen.

There are phase contrast microscopy techniques available, but these have limitations, including a number of technique-dependent artefacts that can lead to problems with interpreting the images. And while they may produce pictures, they do not provide "quantitative" information, i.e.: numerical information that can be used to characterise or measure the specimen.

Confocal scanning microscopy, which became a standard technique in the 1980s with the greater availability of lasers as light sources, is an optical imaging technique used to increase optical resolution and contrast of a micrograph by using point illumination. It entails focussing one or more beams of light into a small spot and, by using oscillating mirrors, raster-scanning the specimen. Fluorescent centres in the specimen react to different illumination wavelengths, and by using a pinhole aperture, only light emanating from a thin focal plane in the specimen can reach the detector. By raising and lowering the microscope stage, information can be acquired from multiple slices through the specimen – i.e. a Z-stack.

Although confocal microscopy is an important technique in current biological and biomedical research, distortion created in specimens at depths beyond 1.5 microns from the cover glass encounters severe distortion, which thus limits the accuracy of the technology.

There are fundamental problems confronting microscopy, however. Moving on to even shorter wavelengths (a fraction of the diameter of an atom), even the most minute error in the lens or the experimental apparatus leads to an impaired image. Thus the images generated by typical electron or X-ray microscopes are significantly more blurred than the theoretical limit defined by the wavelength.

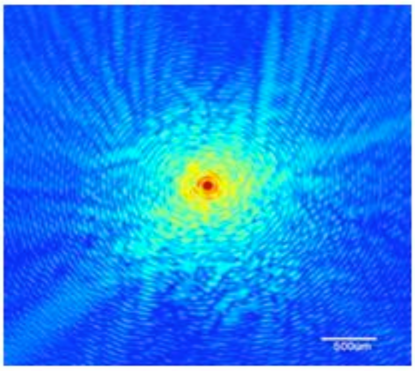
Thus there appears to be a trend towards more complex, expensive equipment in which performance is challenged, perhaps compromised. At the University of Sheffield, Professor Rodenburg and his team devised a novel technique to transfer the task of image formation from physical components (i.e. a lens) to a software algorithm – the Phase Focus Virtual Lens®. This bypasses many of the legacy issues associated with lens-based imaging, and the microscopy market can look forward to a new technological revolution.

Phase Focus Technology – PIE in the Eye

An alternative to conventional microscopy and its more recent developments has been opened up by Phase Focus with its robust, exploitable technique of generating images from diffraction patterns. The Phase Focus Virtual Lens® software allows a computer to 'read' the diffraction patterns caused by the scattering of light from an object. The diffraction patterns contain the information required to make up an image of the object, a process previously believed to be mathematically impossible to achieve. The revolutionary technique can also be used to measure a number of important properties, such as the thickness of a material, and even material type.

Diffraction

Visual:



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Diffraction is a result of the nature of wave propagation, and occurs when any kind of wave – a sound wave, an electromagnetic wave or a matter (e.g.: electron) wave - encounters an obstacle and appears to bend around it. Similar effects are observed when light waves travel through a medium with a varying refractive index.

The classical treatment of wave propagation considers each point on a wavefront as a point source for a secondary radial wave.

On encountering obstacles, or passing through areas of different refractive indices, the resulting propagation of these radial waves forms new wavefronts which combine with each other. The resulting pattern is made up of the sum of these waves, which depends on the amplitude and relative phases of the waves. Waves in phase with each other will have an amplitude equal to the sum of the amplitudes of the individual waves (maxima), while those in anti-phase will cancel each other out for summed amplitude of zero (minima). Diffraction patterns thus have patterns of maxima and minima, with their form determined from the sum of the phases and amplitudes of the waves at each point in space.

The shorter the wavelength, the greater the microscopic detail within the diffraction pattern. Historically lenses have been required to see this detail. But at shorter wavelengths, focussing devices are very costly and difficult to make. For example, electrons in an electron microscope cannot pass through glass lenses, and so have to be shaped by complex "electromagnetic lenses" consisting of magnets and energised coils of wire that can steer the charged electrons.

X-rays pass unchanged through glass lenses, and cannot be steered by electromagnetic lenses either, and so precision-engineered gold "zone plates" have to be used. All such focussing methods used at shorter wavelengths are limited by engineering considerations, and cannot provide the resolution to see the finest details. Moreover, with the range of sensors used today, including the human eye, only the intensity of the waves and not their phase can readily be observed.

The generalised reconstruction of an image of an object from measurements of diffracted waves is a well recognised problem, and is referred to as the "Phase Problem". Phase Focus has a solution to this problem.

It should be noted that diffraction plays a role in optical holography as it uses the interference pattern created by the mutually-coherent (laser) object and reference beams, the object beam having been diffracted by the target specimen. But the requirement for a reference beam makes the instrumentation much more complicated and difficult to use.

In regards to the Phase Focus solution, at its core is ptychography, and the **Ptychographical Iterative Engine (PIE)** algorithm; the patented technology. Ptychography (from the Greek for "fold") uses multiple exposures taken at different, but necessarily overlapping, regions of the object under investigation. The method then takes advantage of the fact that some spatial information can be recaptured by knowing the location of the probe beam. This algorithm, the extended-PIE (ePIE), and associated software are the constituents of Phase Focus Virtual Lens® technology.

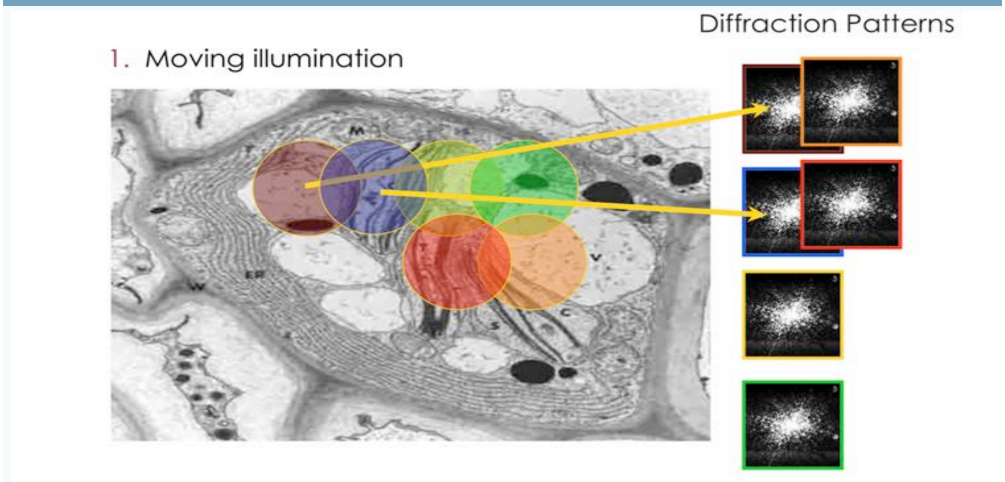
The Virtual Lens

Phase Focus' lensless process comprises two key steps:

Firstly

Illuminating multiple overlapping portions of the specimen (either by moving the beam or the specimen), and recording the associated diffraction pattern. An example of sequential illumination and the associated diffraction patterns are shown in the accompanying figure, numbered 1:

Principle of the Virtual Lens: Data Acquisition



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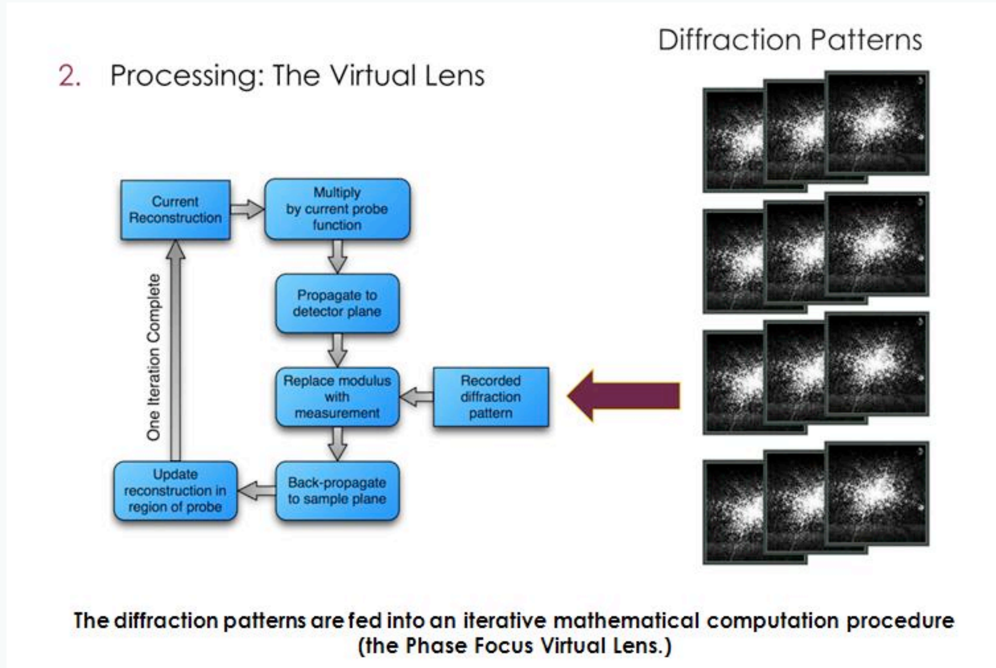
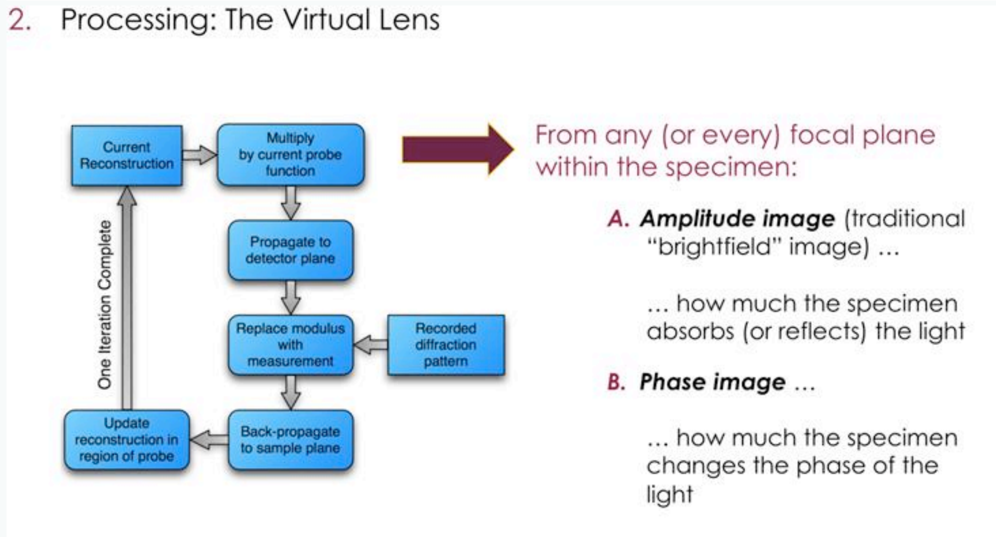
Secondly

The processing stage whereby the image of the specimen is reconstructed from the multiple diffraction patterns using an iterative mathematical computation process, as in figures 2:

Principle of the Virtual Lens: Reconstructing the image





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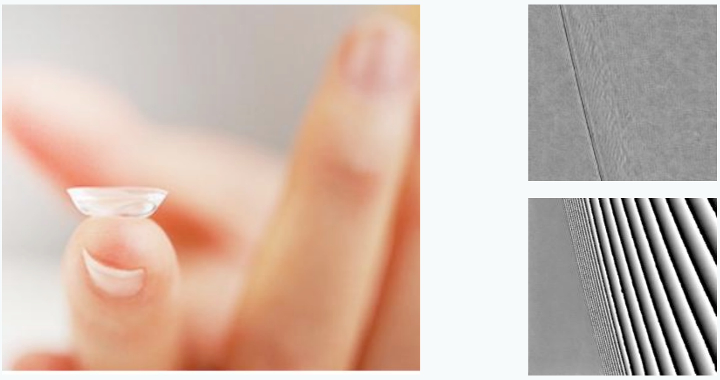
Each reconstruction yields amplitude and phase image data sets. An example of the amplitude and phase image pair from an edge area of a hydrated contact lens specimen is shown below. As the lens is transparent, the amplitude image is generally featureless, as in conventional microscopy, while the phase image consists of successive "fringes" each one of which corresponds to a phase shift of 360 degrees.

Contact lens imaging



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The amplitude and phase data sets can be processed to generate a series of quantitative phase-and-amplitude image pairs focussed at different depths in the specimen. This z-stack feature can be used to:

- Analyse three-dimensional characteristics of the specimen
- Enable post-acquisition focussing.

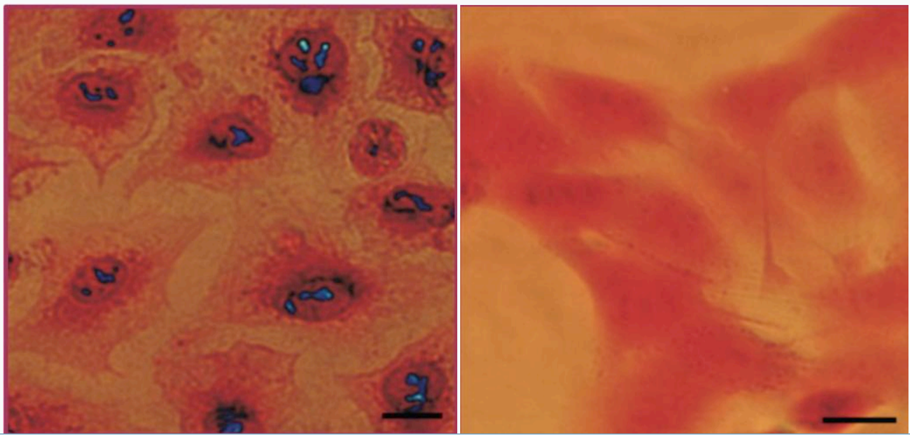
In principle, the technology can be used across the entire electromagnetic spectrum and also for quantum mechanical matter waves.

The Unique Selling Points (USP)

The Virtual Lens has a number of USPs:

- Lens-free
- Focus-free
- Virtual Lens TruWave™ images are content-rich and quantitative, as shown here:

Dead and Live Cells with TruWave



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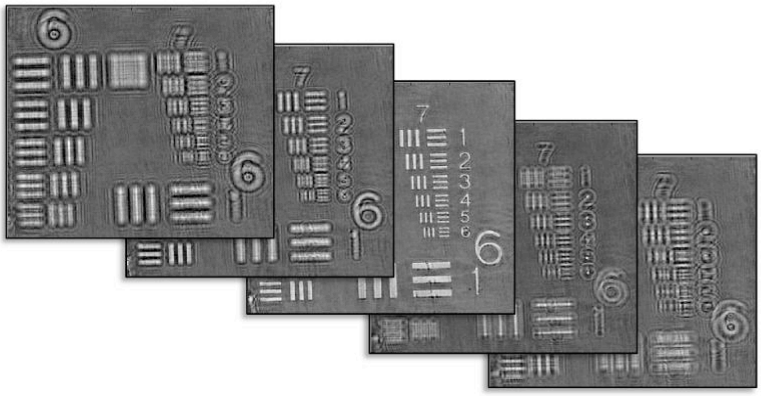
- Superior fidelity
- Superior contrast resolution
- Superior spatial resolution
- Virtual Lens TruWave™ images can be displayed at any focal plane with no additional acquisition required:

Multi-level imaging with TruWave™



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USPs across the Spectrum

These are well summarised by the Company itself in the table below:

Virtual Lens applications across the spectrum

Wavelength / USP	Visible	Electron	X-Ray
Lens-free	Removes the requirement for … … multi-element glass objective lenses … and enables large working distances	… electromagnetic aberration-correctors	… high aspect ratio zone plates
Quantitative	E.g.: thickness; refractive index; dielectric constant; inner potential; magnetic field …		
Superior fidelity	E.g.: no lens-related aberrations or asymmetries; no "phase contrast" artefacts; flat baseline		
Superior contrast resolution	Stain-free imaging of transparent specimens; improved feature characterisation		
Superior spatial resolution		Beyond electromagnetic lens limit (~0.5Å)	Beyond hard X-ray zone plate limit (~30nm)
Reproducible	Quantitative vs. qualitative => operator-independent; automatable		

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Intellectual Property (IP)

Phase Focus has nine patent application families, comprising two originally filed by the University of Sheffield and assigned to Phase Focus, plus seven filed directly by Phase Focus itself.

The company's strategy is to prosecute all patent applications internationally.

The patent applications and awarded patents filed originally by the University of Sheffield are:

- **WO 2005/106531,** which protects the original Phase Focus Virtual Lens algorithm "Ptychographical Iterative Engine (PIE)". This was filed in April 2004.

Patent filing

Issued in Eurasia	No. 011004	December 30, 2008
Issued in USA	No. 7,792,246	September 7, 2010
Accepted in Australia	No. 2005238692	September 30, 2010

Company

- **WO 2010/035033,** which protects an extension of the Phase Focus Virtual Lens algorithm – "Extended Ptychographical Iterative Engine (ePIE)" – and was filed in December 2008.

Phase Focus has directly filed the following patent applications:

- **WO 2008/142360:** protects a method for three dimensional imaging using the Phase Focus Virtual Lens algorithm. This was filed in May 2007.
- **WO 2009/077779:** protects specific implementations and improvements of the algorithm, and was filed in December 2007.
- **WO 2010/035033:** protects a method for the parallel processing of the algorithm. Filed in September 2008.
- **WO 2010/119278:** protects specific implementations and improvements of the algorithm. Filed in April 2009.

- **GB N0. 1006593.6:** protects a method for surface property measurements using the Virtual Lens algorithm. Filed in April 2010.
- **GB No. 1010822.3:** protects a calibration method for the algorithm. Filed in June 2010.
- **GB No. 1016088.5:** protects a method of three-dimensional imaging using the algorithm. Filed in September 2010.

The company has also secured registration of the trademark "Phase Focus Virtual Lens" (Registered Trademark No 2509314, February 2009).

Phase Focus is an industrial participant on the University of Sheffield's £4.3 million "Ultimate Microscopy" research programme that is led by the Company's co-founder, Professor John Rodenburg. Phase Focus's parent company, Fusion IP has an exclusive 10 year IP pipeline agreement with the University of Sheffield via which it has the right to acquire or license any Sheffield IP. Via this pipeline, Phase Focus may therefore gain access to any Sheffield IP that is generated within the Ultimate Microscopy research programme. Thus far, two University of Sheffield patent applications have been assigned to Phase Focus via this mechanism.

Professor Rodenburg is an employee of the University of Sheffield and provides services to Phase Focus under a Secondment Agreement. This allows him to spend 20% of his normal working hours on Phase Focus matters, and any IP rights generated by him during these Secondment Duties are owned by Phase Focus. IP generated outside the Secondment Duties may be assigned to Phase Focus under the terms of the IP pipeline agreement of Fusion IP.

MANAGEMENT

Mr. David Baynes, **Chairman,** is CEO of Fusion IP plc, the AIM-listed University of Sheffield intellectual property commercialisation firm and Phase Focus's lead investor. David previously worked at Celsis International plc from its incorporation to its flotation on the full list of the London Stock Exchange in July 1993; Toad plc (now TG21 plc), which he co-founded, and was took from start-up to a full listing on the London Stock Exchange; Whereonearth Limited; and Codemasters Limited.

Dr. Ian Pykett, CEO, has 25 years' international experience in the commercialisation of high-tech innovations. He has previously worked as CTO of Intermagnetics General Corporation, where he grew a three-person R&D group into an energy technology spin-out subsidiary valued at $160 million; and as co-founder and CEO of Advanced NMR Systems, Inc. that increased its value to $75 million from its flotation value of $6.5 million. Ian was awarded the 1997 Rank Prize in Optoelectronics for Advanced NMR's commercialisation of an innovation now used world-wide for functional MRI brain imaging. He has advised on innovation commercialisation and intellectual property asset management for university, RDA, start-up, SME and plc clients, and is Chairman of the UK STFC research council's Innovation Partnership Scheme panel. A graduate of the universities of London, Birmingham and Nottingham, Ian has been elected to Fellowships of the Institute of Physics, and the Institute of Physics and Engineering in Medicine.

Professor John Rodenburg, **Chief Scientific Officer,** is recognised internationally for his pioneering development of the Ptychographical Iterative Engine (PIE) – the phase retrieval algorithm that forms the basis of the Phase Focus Virtual Lens. A Professor in the Department of Electronic and Electrical Engineering at the University of Sheffield, he is currently Principal Investigator on the £4.3 million "Ultimate Microscopy" lensless microscopy research programme, which is funded via the Engineering and Physical Sciences Research Council's Basic Technology mechanism that "supports only basic, high quality technology research and training by selecting the most exciting and innovative ideas and the best people." A graduate of the universities of Exeter and Cambridge, John has been elected to Fellowships of the Institute of Physics, and the Royal Microscopical Society.

Dr. Gary Gibson, **Director of Sales and Marketing**, has over 12 years of experience working in high technology industries both in Europe and also in the US. He has held senior positions in a number of different companies, both blue chip and start-up such as Intense, Kromek and JDS Uniphase. He played a key sales role at Bede Scientific where a significant fraction of the company's revenues were realised through his efforts. In addition to his sales and marketing experience he has a strong technical background with a PhD from Imperial College, London, where he won a number of scholarships and awards. He worked as a post-doc in the University of Cambridge prior to his move into industry.

Dr. Neil Loxley, Non-Executive Director, is CEO at Instrumental Ltd., a firm that sells wireless telemetry systems. He was formerly CEO at Bede plc, the driving force in transforming Bede Scientific Instruments from a specialist scientific instruments company into a global semiconductor equipment company. A graduate of the universities of York and Durham, Neil is a Fellow of the Institute of Physics, and is a non-executive Director of the White Rose Technology Seedcorn Fund.

Dr. Martin Humphry, Technology Director, was appointed post-doctoral research fellow at Nottingham University, following the award of his PhD in the area of nanotechnology instrumentation, whereupon he founded and led a spin-out company to commercialise a novel scanning probe microscope technology. Previously he had been a Design Consultant for Reuters ADL, where he was technical lead on the development of a real-time foreign exchange pricing system that is now in use throughout the world in many of the world's largest banks.

STRATEGY

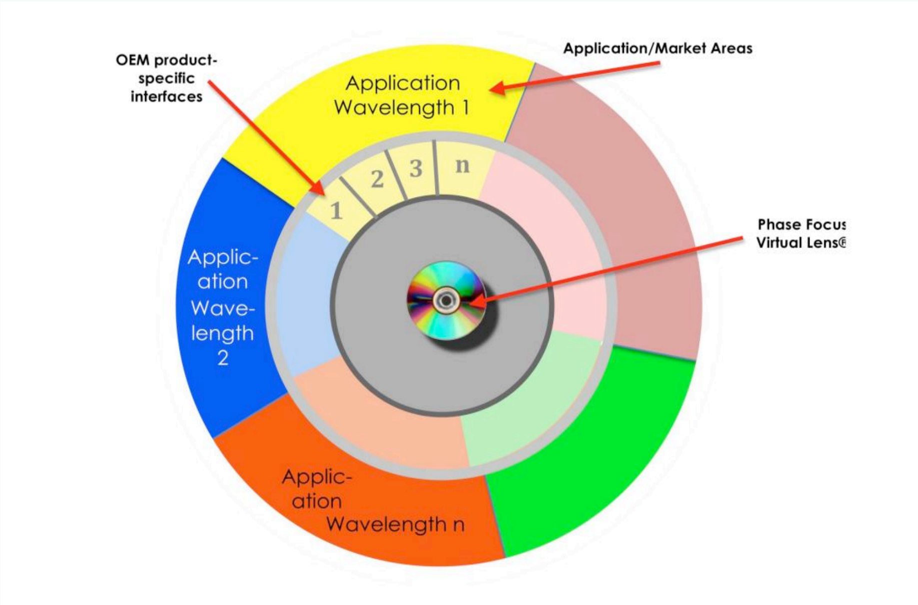
Business Model and Route to Market

The company aims to develop and sell its technology as a package comprising the Virtual Lens algorithm optionally embedded in an optimised processing hardware environment. Currently the hardware comprises the GeForce 285 graphics processing unit (GPU) from NVIDIA, a leader in visual computing technologies, with a host PC. Phase Focus' processor-embedded Virtual Lens thus comprises the Virtual Lens algorithm and the processor code that optimises the operation of the algorithm.

The Virtual Lens algorithm (and, where relevant, the processing hardware) can then be integrated with existing imaging systems, and marketed by the system vendor either as a system upgrade or an add-on accessory. Phase Focus anticipates a co-development process with an established Original Equipment Manufacturer ("OEM") for each application, which will integrate the Virtual Lens into the OEM's existing product lines, or in a new OEM product.

This can be done over a range of applications and wavelengths, but with Phase Focus retaining ownership of the processor-embedded Virtual Lens and the processor code that optimises the operation of the algorithm. The OEM will typically own the interface between the processor-embedded Virtual Lens and the OEM's product. Representing this diagrammatically:

Sell Strategy



Company

In certain cases, and particularly in the optical wavelength regime, the Company may choose to demonstrate and refine the USP value proposition more rapidly by making a limited number of "stand-alone" instruments that incorporate the Virtual Lens technology, and selling such systems to early adopter end users.

APPLICATIONS

Phase Focus' Virtual Lens technology is gaining traction in a number of applications thanks to its ability to operate over the electromagnetic spectrum, its ability to generate depth-resolved images at very fine resolution, to use contrast effects of different material characteristics like refractive index and dielectric constant for previously unobtainable imaging, and to obtain accurate numerical outputs.

Significant progress has been made in the following applications

- Stain Free Live Cell Imaging
- Semiconductor Process Control
- Ophthalmic Lens Metrology
- Engineering Metrology
- Electron Microscopy
- Coherent X-Ray Microscopy

Each of these applications are now discussed and the significant technological benefits of transferring the task of image formation away from the conventional lens to a software algorithm are outlined.

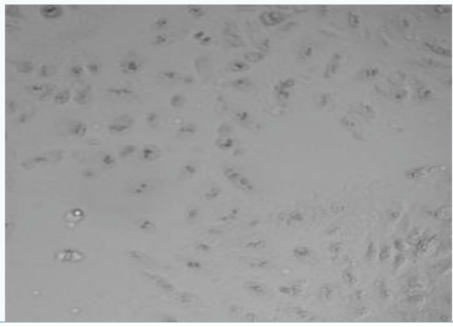
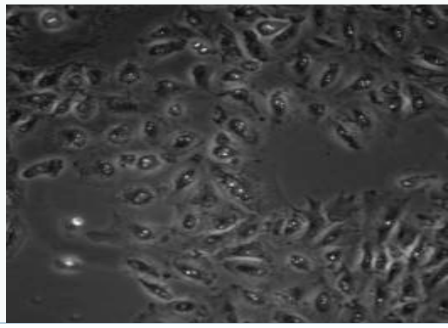
Stain-free Cell Imaging

'You get what you do not see'

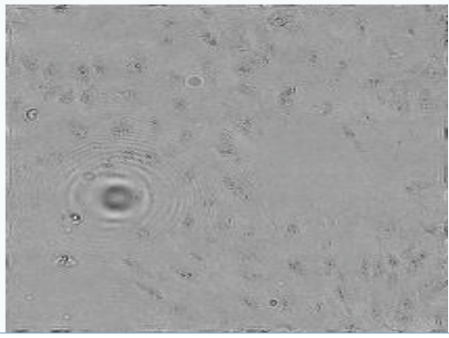
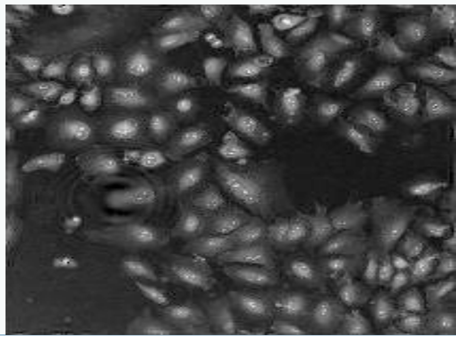
The past decade has witnessed an enormous growth in the application of optical microscopy for micron and submicron level of investigations dramatically transforming biological sciences and becoming one of the most widely used imaging methods in biomedical research due to its molecular specificity and fast image acquisition.

The Phase Focus Virtual Lens® appears to have the right characteristics to turn into an important and disruptive tool that could prove extremely valuable in improving research outcomes by providing better image and spatial resolution and content-rich images, but also quantitative (physical thickness, surface topography and refractive index) microscopy data. One of the major advantages of TruWave microscopy is that live cells in specimen can be examined without staining.

Additionally, it removes halos and shadowing effects associated with conventional phase-contrast (see pictures below) and has been designed to be '*researcher friendly'* to be either integrated with existing lab instrumentation or replace the conventional microscope lens system.

Brightfield (conventional white light)	**Zernike Phase Contrast (conventional white light) Bright halos around the features**
	

Source: Phase Focus Application note No. AN03

Virtual Lens Brightfield image	**Virtual Lens Phase image (no halos)**
	

Source: Phase Focus Application note No. AN03

The quantitative phase information acquired by the Virtual Lens has multiple benefits in cell imaging:

- high contrast without stains
- free of conventional distortions (no conventional phase contrast microscopy artefacts; no lens-associated aberrations)
- wide variety of non-contact geometries (fully lensless near-field imaging; lens assisted imaging with large working distance (≤90cm)
- large fields of view within extended specimens (user-defined; independent of resolution)
- perfect focus every time (post-acquisition through-focal series reconstruction and/or interactive focal plane selection) which could facilitate high speed reading in robotic production line environments,
- cell characterisation and feature extraction (quantification of cell thickness; shape; refractive index; simple segmentation)
- easy to use and reproducible

TruWave overcomes the limitations currently present in Phase Contrast microscopy which is artefact-ridden, irreproducible and the '*picture taking*' aspect of the technology.

TruWave intrinsic features make its initial potential use particularly suitable in two key research areas:

- cell assays (including high content screening) where it is important to **MEASURE** the numbers and types of cells and their biological status (dead, alive, or dying or reproducing, etc.);
- **PROCESS CONTROL** and **MANUFACTURING** of stem cells and cell constructs for regenerative medicine application. The quantitative nature of the information provided by the technology, which includes the ability to measure hydrogel substrates in cell constructs.

To our knowledge there is no other close to, or commercialised, '*lensless*' technology and that enables the wide-area examination of live cells without staining.

According to a recent stem cell global market analysis conducted by SelectBioSciences, 52% of primary research application of stem cells focuses on regenerative medicine/cellular therapy, followed by basic research (29%) and drug discovery, development and toxicity testing/screening (19%) with academic institutions/universities and biotechnology companies accounting for 52% and 30% respectively. Geographically the US and Europe account for 48.4%, and just over 20%, respectively. Within Europe, the UK is the largest market representing 8.4%.

Semiconductor Fabrication

Overlay

The dramatic achievements in shrinking semiconductor feature sizes and the accompanying reductions in cost per function have underpinned the rapid diffusion of electronics technology in the past 20 years.

Feature sizes have moved into the deep sub-micron level and the semiconductor technology roadmap points to further decreasing feature size and the introduction of a broadening range of new materials. While DRAMs ("Dynamic Random Access Memory") led the way in terms of the reduction in feature size, other more complex components are forecast to become the front runners.

Key Lithography-related Characteristics by Product:

Near-term Years

YEAR OF PRODUCTION	2009	2010	2011	2012	2013	2014	2015	2016
Flash Uncontacted Poly Si ½ Pitch (nm)	38	32	28	25	23	20	18	15.9
DRAM stagger-contacted Metal 1 (M1) ½ Pitch (nm)	52	45	40	36	32	28	25	22.5
MPU/ASIC stagger-contacted Metal 1 (M1) ½ Pitch (nm)	54	45	38	32	27	24	21	18.9
MPU Printed Gate Length (nm)	47	41	35	31	28	25	22	19.8
MPU Physical Gate Length (nm)	29	27	24	22	20	18	17	15.3

Long-term Years

YEAR OF PRODUCTION	2017	2018	2019	2020	2021	2022	2023	2024
Flash Uncontacted Poly Si ½ Pitch (nm)	14.2	12.6	11.3	10.0	8.9	8.0	7.1	6.3
DRAM stagger-contacted Metal 1 (M1) ½ Pitch (nm)	20.0	17.9	15.9	14.2	12.6	11.3	10.0	8.9
MPU/ASIC stagger-contacted Metal 1 (M1) ½ Pitch (nm)	16.9	15.0	13.4	11.9	10.6	9.5	8.4	7.5
MPU Printed Gate Length (nm)	17.7	15.7	14.0	12.5	11.1	9.9	8.8	7.9
MPU Physical Gate Length (nm)	14.0	12.8	11.7	10.7	9.7	8.9	8.1	7.4

Source: International Technology Roadmap for Semiconductors 2009

A number of optical techniques are used in semiconductor fabrication to monitor and control the process. The integrated circuits on silicon wafers are currently manufactured in a sequence of steps, with each of these steps comprising the formation and patterning of the different materials involved in building up transistors to form functional units. The challenge is, as the 45nm feature size is shrunk even further, to ensure accurate layer-to-layer registration over 10 – 20 layers on the wafer surface.

Overlay control refers to this alignment, and overlay metrology solutions with both higher measurement accuracy/precision and process robustness are key factors when addressing this application area. However, this becomes increasingly challenging for lens-based equipment due to residual aberrations in the optical system, particularly in the microscope objective lens.

The Virtual Lens offers a very competitive solution as it suffers no lens distortions; it can generate images from multiple depths with no further acquisition required, and it provides exceptionally high contrast.

Thin Film

Another key application of optical technology in semiconductor fabrication is thin film metrology. It has been found that reducing the thickness of a film to below 100 nanometres induces a strong correlation between the material’s optical properties and its physical dimensions. Techniques gaining ground in this application include the use of electron beam metrological systems and ellipsometry, which uses the change in polarisation of reflected light to glean information on film thickness and refractive index measurements to characterize film thickness for single layers or complex multilayer stacks.

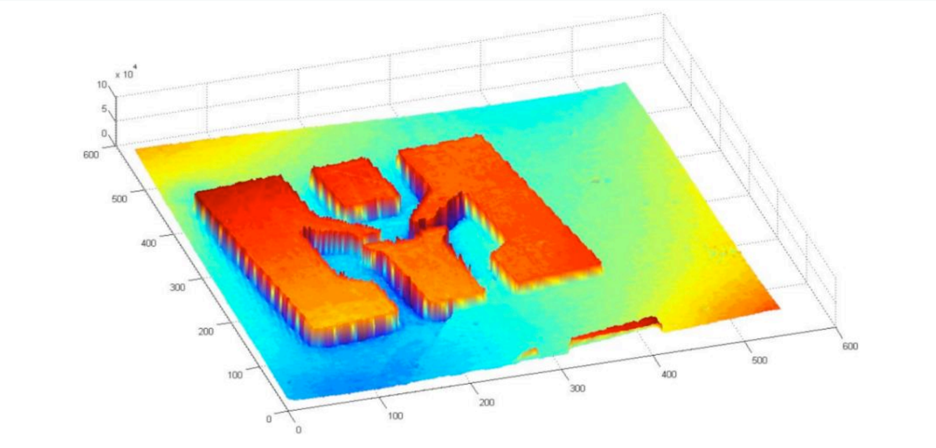
In reflection mode, the Virtual Lens can offer 6 Ångstrom (0.6 nanometre) height sensitivity with sub-micron lateral resolution over arbitrarily large fields of view, again offering a leading edge solution to a crucial but costly measuring process.

Thin Film and Overlay applications within the automatic manufacturing process can lead to increased quality control and efficiencies. Phase focus is already in discussion with major semiconductor manufacturers.

Gold on III-V semiconductor (Material-specific contrast)

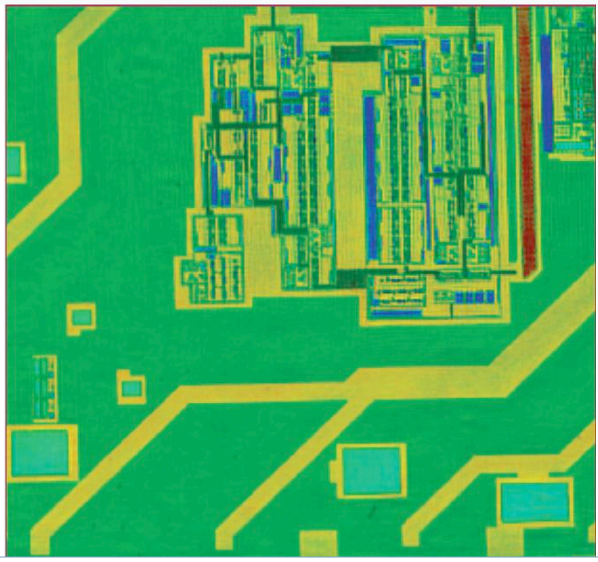
Company

Physical thickness and surface topography, by contrast:



Company

Semiconductor wafer imaging



Company

Lens Metrology

Surprisingly, there are currently no widely-available techniques to measure the thickness and morphology of soft contact lenses and intra-ocular lenses in their hydrated state – i.e., as they would be when in the eye. This is a huge drawback for quality control and leads to inefficiencies in the manufacturing process.

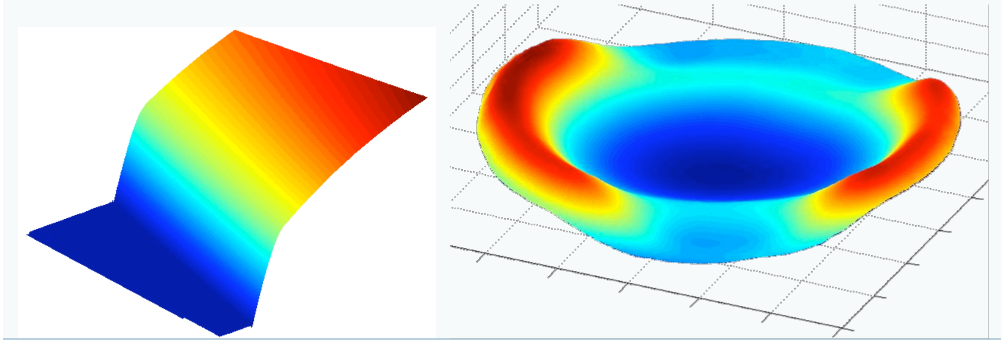
The reasons for this are, first, that ophthalmic lenses are transparent and difficult to see using conventional microscopes; and, second, that they are very soft and cannot be measured using conventional mechanical metrology methods.

The importance of an accurate metrological technique for contact lenses lies in the need (i) to ensure that the manufactured lenses meet the required design parameter specifications (quality assurance); and (ii) to ensure that adequate oxygen can reach the eye through the lens in order to ensure corneal health. Oxygen transmissibility through the lens is inversely proportional to the thickness of the lens. Measurements are currently taken on unhydrated lenses, or on lenses removed from the production line and physically sliced, thus the measurements are extremely labour-intensive or are not representative of the hydrated lens. Other factors also impinge, for example, multifocal and toric lenses have complex thickness profiles.

The Phase Focus Virtual Lens allows measurement of soft contact lenses in their natural hydrated state. Whole lens thickness measurement and high resolution edge profiling can be determined, and optical thickness changes can be demonstrated, viewed and quantified over the entire lens area. The technology can be applied equally effectively to single-vision, multi-focal and toric lenses.

Phase focus is already in discussions with lens manufacturers to incorporate the virtual lens into the contact lens manufacturing process.

Contact lens imaging



Company

The Virtual Lens also has applicability to the intraocular lens market in cataract surgery, and for the lenses used in consumer electronics devices including DVD and CD players and mobile phone handsets.

Electron Microscopy

In electron microscopy – capable of higher resolution than optical microscopy because of the shorter wavelengths associated with the electrons – lenses comprise magnetic coils that direct and focus the electrons. The use of electron beams requires a high vacuum to prevent the electron beam being scattered by gas molecules present, which in turn leads to evaporation of water from biological specimens.

The more familiar electron microscopy approaches are 1) scanning electron microscopy (SEM), in which a beam is raster-scanned across a specimen, and a three-dimensional picture of the surface can be built up from back-scattered and ejected electrons from the specimen; and 2) transmission electron microscopy (TEM), in which a flood beam of electrons are transmitted through a specimen and electron diffraction and direct imaging techniques are used to derive images.

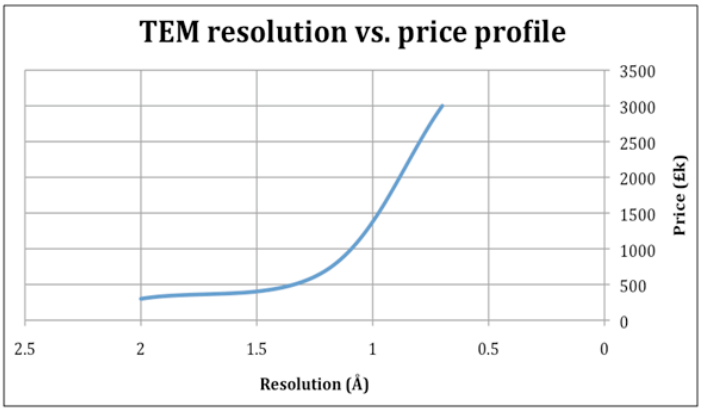
TEM provides the better spatial resolution – around 1-2 Ångstroms – while SEM can image a comparatively large area.

In addition to the requirement for a high vacuum, electron microscopy suffers from additional problems:

- Possible damage to sensitive specimens by the electron beam;
- TEM is limited to specimen thicknesses of a few hundreds of nanometres due to the electron's limited penetration of solids;
- High resolution instruments must typically be shielded from external magnetic fields and vibration;
- Spatial resolution is limited by the capabilities of the electromagnetic lens.

The last point is significant in terms of the extremely high cost of new high resolution systems, with the cost v resolution curve being non-linear and reflecting the conventional lens resolution plateau (see below). An engineering limit of approximately 0.5 Angstroms is being approached.

Resolution vs price for transmission electron microscopes



Source: Company

Applying the Virtual Lens to electron microscopy, there are no immediate resolution limits, and a factor of around 20 in resolution improvement is in principle feasible. While the atomic vibrations may limit the scientifically-useful resolution below about 0.1 Ångstrom, even this resolution is around five times better than the best electron microscope resolution ever obtained. This will be possible without the high cost of high-end electromagnetic lenses. The Virtual Lens can also enable TEM on SEM microscopes, thus providing a "two-in-one" instrument and saving on capital costs, laboratory real estate and service costs.

Similarly, existing electron microscopy equipment can be significantly upgraded by retrofitting with a Virtual Lens, thus saving the capital cost of a higher end unit. Phase Focus has already agreed a Term Sheet with a leading electron microscopy products vendor.

Coherent X-ray Microscopy

There are major applications of X-rays in crystallography and materials analysis. However, X-rays need lithographically fabricated gold zone plates, which are difficult to manufacture, typically costing US$35-45k to focus them, but become problematic for high energy "hard" X-rays. Phase Focus' Virtual Lens, however, eliminates the need for zone plates.

The pre-eminent source of coherent X-rays is synchrotron radiation. A synchrotron is a particle accelerator in which a magnetic field (which controls the motion of charged particles – typically electrons for X-ray purposes) and the electric field (to accelerate the particles) are synchronised with the travelling particle beam. By accelerating electrons to near light-speed, a synchrotron generates brilliant beams of light from infra-red to X-rays which are used for academic and industry research. A synchrotron consists of an assembly of components used to produce, confine and maintain a high energy electron beam in a closed orbit in a storage ring for periods of several hours while the electrons produce synchrotron light for a wide variety of experiments. The X-rays generated by synchrotrons are accessed by experimenters via beamlines, and are particularly useful as sources for microscopy because of their high intensity and high coherence. X-ray synchrotrons are used in imaging, scattering (crystallography) and spectroscopy modes. X-ray microscopy is the most immediately applicable to the Virtual Lens.

X-ray microscopy uses the synchrotron light-source beam to obtain high spatial resolution images of the specimen under study. It is used in diverse research areas such as cell biology, lithography, infrared microscopy, radiology, environmental science and X-ray tomography. An advantage of X-ray microscopy compared to electron microscopy is that wet biological samples can be studied, since there is no requirement for the specimen to be enclosed within a vacuum environment.

X-ray microscopy with the Virtual Lens would enable the nano-imaging of amorphous or partially-crystalline bio-materials (muscle and collagen, for example), and multi-focal plane analysis of different layers within X-ray transparent VLSI ICs.

A large number of individual researchers who obtain data from synchrotrons need a means to process the data in their home laboratories, and this user base represents a large target market for Phase Focus. In 2009 there were 105,000 synchrotron users per year, and this number is growing at an estimated 15% per annum.

Markets

The estimated sizes of the available markets for the Virtual Lens are shown in the table below:

Scale of Opportunity

Wavelength regime	Market	Application	Est global market size, US$bn
Optical	Semiconductor metrology	Overlay, film thickness, critical dimension metrology	2.1
Optical	Cellular assays	Automated analysis of proliferation, cell loss, motility and division	0.7
Optical	Contact lens	Measurements in natural hydrated state	5.3
Optical	R&D microscopy	Stain-free live cell microscopy	0.7
Electron	R&D microscopy	Ultra-high resolution and TEM-on SEM "two-in-one" instrument	1.5
X-ray	X-ray synchrotron microscopy	3D analysis of VLSI chips and quasi-crystalline proteins (eg collagen)	0.2

Source: ED

Competitors

There are a number of technologies in the academic and commercial sector that utilise a number of techniques that can obtain numerical phase information, but none offers the full range of USPs that the Phase Focus Virtual Lens technology offers. Specifically, digital holography requires additional high-end hardware and precise optical alignment of reference beams, none of which are required in the Virtual Lens implementation.

Holography requires extremely advanced expertise for operation in the electron regime and is not available as a tool for routine use. Certain other methods still require the use of expensive and inherently imperfect lenses, or mandate acquisition of data from the entire specimen simultaneously which, for high resolution microscopy, either places extreme demands on imaging camera hardware or restricts implementation to extremely small specimens.

FINANCIALS

Phase Focus is developing applications in the optical, X-ray and electron microscopy areas, with their anticipated timeline of these developments shown here:

Timeline of developments

Company, ED

Forecasts are underpinned by the OEM and end user relationships already demonstrated. The company is in in-depth technology evaluation collaborations with a leading electron microscopy products vendor, a leading engineering metrology solutions vendor and leading semiconductor metrology system vendors.

End-user sales and product evaluations include York University for live cell imaging, multiple ophthalmic lens manufacturers and a number of academic institutions.

As mentioned in the Strategy section, Phase Focus will typically enjoy four revenue streams:

- Funded non-recurring engineering co-development contracts
- Licences for the Virtual Lens algorithm and associated optimised processing code
- Virtual Lens upgrade licenses
- Software service contracts.

In November 2010, the company agreed with a leading electron microscopy firm the key terms of an license to integrate the Phase Focus Virtual Lens within commercial electron microscopy instruments. This should kick-start electron microscopy sales in 2012 with an anticipated strongly growing revenue stream from this first OEM agreement, subsequently to be augmented by other sales to the sector.

Forecasts

Early revenues are expected to derive from the Company's strategy of "priming" the market with sales to early adopters of complete stand-alone instruments that incorporate the Virtual Lens technology; and, in certain applications, via up-front license or exclusivity fees. More substantive ongoing per-unit royalty revenues will then accrue as applications are migrated from stand-alone platforms into existing or new OEM instruments.

In certain cases demonstrable interest already exists for the Company's technology in both the automated on-line process control context, as well as in more flexible instrumentation for end user R&D laboratories. A case-in-point is the Company's Virtual Lens-enabled ophthalmic metrology capability which is expected both to replace highly labour-intensive quality assurance procedures on the production line, and also to provide a powerful tool for the rigorous laboratory testing of new lens designs.

Multiple income opportunities derived from royalties, fees and complete end-user system sales in a broad diversity of markets reduces business risk. Because the Virtual Lens algorithm is essentially identical for all applications, and because there is no requirement for a large capital infrastructure, the Company may allocate its resources dynamically to benefit from underlying market growth in specific sectors, and to exploit new opportunities expected to arise as a result of rapid parallel developments in micro-engineering and nano-technology.

Early revenues for optical applications of the Virtual Lens are expected to accrue from sales into the ophthalmic lens sector, followed by substantive sales for general engineering metrology. Sales into the semiconductor process control market are expected to grow rapidly as the statistical accuracy and reliability of the technology are demonstrated. Market confirmation of this broad range of optical materials applications, together with further demonstration of the optical Virtual Lens in the life sciences, will accelerate integration of the capability in the large and rapidly growing R&D optical microscopy market.

Revenues for electron applications will be driven initially by the recent agreement of key terms with a leading global electron microscopy player, and revenues from the X-ray sector will flow from recent demonstrations of the technology at a number of the world's most advanced synchrotron facilities.

Since the largest proportion of revenues is driven by royalties from licenses, the gross margins can be expected to be high. Overheads can be expected to be relatively lower than for many software-based firms because sales to the market are made via a limited number of OEMs rather than directly to a large number of end users, thus substantially reducing marketing expenses. Together with multiple revenue streams from large markets, these factors indicate an unusually early break-even point for a new high-growth technology company, and suggest that this may be the last opportunity to invest in this revolutionary disruptive business opportunity.

Valuation

The company has raised £1.6m via seed capital funds, and the current shareholders and their holdings in the company are shown below.

Shareholders	
Fusion IP, Sheffield	54.2%
John Rodenburg	12.6%
Ian Pykett	1.5%
Helen Faulkner	1.1%
Viking Fund	5.1%
White Rose Technology, Ltd	18.6%
South Yorkshire Investment Fund	6.2%
Braveheart Investment Group	0.6%
Staff options	*6.2%*

Company

DCF

A discounted cash flow analysis based on our 5-year forecasts, and conservative assumptions regarding long term growth rate and the discount factor to be applied (1% and 33% respectively) yields a fair value of £11.0m pre-money.

Equity values from DCF analysis, £m

Long term Growth Rate	0%	1%	2%	3%	4%
Discount Rate					
25.00%	17.6	18.1	18.6	19.3	19.9
26.00%	16.4	16.9	17.4	17.9	18.5
27.00%	15.4	15.8	16.2	16.7	17.2
28.00%	14.5	14.8	15.2	15.6	16.1
29.00%	13.6	13.9	14.3	14.6	15.1
30.00%	12.8	13.1	13.4	13.7	14.1
31.00%	12.1	12.3	12.6	12.9	13.2
32.00%	11.4	11.6	11.9	12.1	12.4
33.00%	10.8	**11.0**	11.2	11.4	11.7
34.00%	10.2	10.4	10.6	10.8	11.0
35.00%	9.6	9.8	10.0	10.2	10.4
36.00%	9.1	9.3	9.5	9.7	9.8
37.00%	8.7	8.8	9.0	9.1	9.3

Source: ED

Given the early stage of the company, the current value can be expected to be at a discount to this fair value. Even applying a harsh further 50% discount still yields a valuation of £5.5m.

We would expect successful execution in the near and mid-term timeframe to result in a valuation trending towards the fair value, and then, with the growth trajectory firmly established, the discounts applied can be expected to erode rapidly.

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