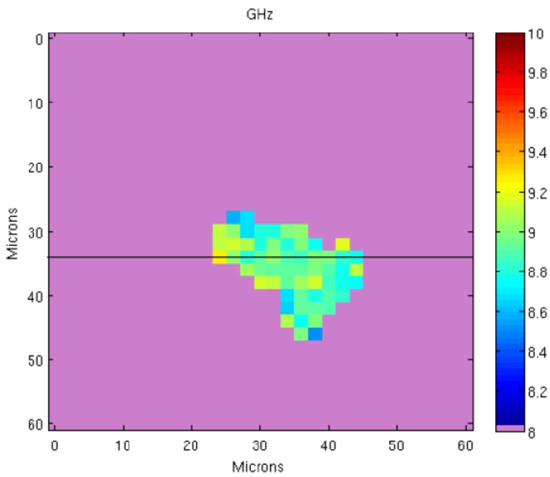
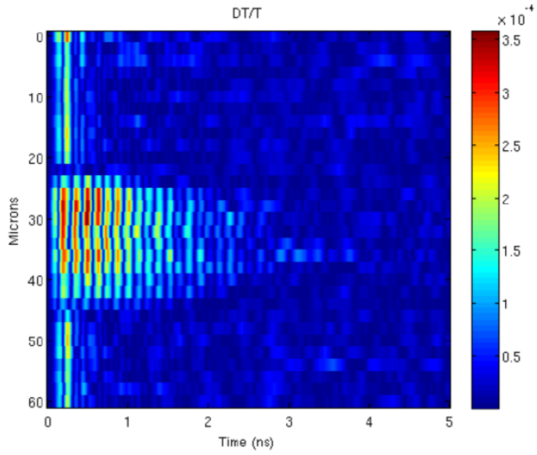
Optics + Ultrasound II

Sponsored by: Optical and Physical Acoustics Groups, Institute of Physics,
Applied Optics Nottingham,
EPSRC





Full-day meeting, Lecture Theatre B3, Life Sciences Building, University of Nottingham [1]
There is no registration fee for this meeting but please register in advance for catering purposes.
To register email Harsha Brooks (Harsha.Brooks@nottingham.ac.uk)
Enquiries to Steve Morgan[2] or Matt Clark [3]

Provisional programme 21 May 2014

(see below for travel advice etc)

1 Coffee + registration 10:00-10:30

2 Morning session

Time: 10:30-10:45
Title: Cheap Optical Transducers (CHOTs) for in-situ application and ultrasonic testing
Author(s): Victoriya Ageeva
Address: Applied Optics, Faculty of Engineering, University of Nottingham
Abstract: Cheap optical transducers (CHOTs) are patterns on the surface of a component activated by lasers to generate and detect ultrasound. Excited optically, with minimal surface impact, and fully customisable, CHOTs provide a simple alternative to conventional piezoelectric transducers, offering wireless, remote operation. Of particular interest is application of CHOTs for in-situ ultrasonic inspection of hard-to reach and complex-geometry components such as those of aero-engines. Endoscopic CHOT pulser uses optical fibres to provide flexible instrumentation for testing of components with complex access paths. It is complemented by the development of the alternative CHOT fabrication methods to allow application of sensors

[1] Building 23, http://www.nottingham.ac.uk/sharedresources/documents/mapuniversitypark.pdf)
[2] steve.morgan@nottingham.ac.uk
[3] matt.clark@nottingham.ac.uk

in-situ, onto large and curved parts, as well as those already in service, challenging for laboratory-limited methods. The g-CHOTs (used for generation of surface acoustic wave) produced on film carriers to allow transfer of the transducer and application onto components in-situ are presented, including fabrication and functionality test results.

Time: 10:45-11:00
Title: Analysis of the fundamental torsional guided wave field within a hollow cylinder using a 3D-FFT
Author(s): Keith Thornicroft[1,2], Alex Haig[2], Cristinel Mares[1] and Peter Mudge[2]
Address: [1] School of Engineering and Design, Brunel University. [2] TWI Ltd, Granta Park, Great Abington, Cambridge, CB21 6AL.
Abstract: The field of guided wave testing (GWT) is a relatively new development within the non-destructive evaluation sector. The market for this technology has been driven by pipeline operators who have a need to screen for corrosion and degradation of their pipeline. In order to improve the detection capability of the guided wave tooling is it important to be able to optimise the output of the transducer array. This paper describes an experimental procedure which was implemented to quantify the output of a circumferentially distributed transducer array. Using a scanning laser vibrometer it was possible to sample an area of the pipe away from the transducer array and measure the displacement behaviour at each discrete point. With vibrometry information gained from both circumferential and axial positions over a range of frequencies, a 3D-FFT technique was developed that reveals circumferential mode order and axial wavenumber both of which are dependent upon frequency. The resultant plot shows the contribution of wave modes generated by the circumferentially distributed transducer array as received by the vibrometer.

Time: 11:00-11:15
Title: Spatially resolved acoustic spectroscopy: a laser ultrasonic technique for materials characterisation
Author(s): Wenqi Li, Richard Smith, Jethro Coulson, Matt Clark, Mike Somekh and Steve Sharples
Address: Applied Optics, Faculty of Engineering, University of Nottingham
Abstract: Material characteristics such as strength, stiffness and fracture resistance are strongly related to the underlying microstructure. In order to predict the mechanical behaviour of industrial materials such as titanium, nickel and their alloys, detailed knowledge about their texture is required. A robust measurement tool is introduced which can be used to determine the crystallographic orientation of a material.

This is achieved by using a laser ultrasonic technique spatially resolved acoustic spectroscopy (SRAS) combined with a numerical surface acoustic wave (SAW) velocity model. The SRAS technique can be used to obtain SAW velocity information on the local area where the waves are generated. There are two ways to implement the technique; in both methods the SAW excitation pattern is generated by projecting a grating pattern of laser light. By varying the frequency by using a broadband laser in combination with a fixed grating, the local velocity v can be calculated, through $v = f\lambda$ where f is the frequency and λ is the grating period. The model predicts the SAW velocity from the material's elastic constants; a search algorithm termed the overlap function is used to compare the SRAS data to the model to determine the crystallographic orientation. We examined a range of materials commonly used for industry. Comparisons between SRAS and electron backscattered diffraction are presented. This is an innovative and all-purpose NDT technique for materials manufacture monitoring and quality control.

Time: 11:15-11:30
Title: Recent progress in laser ultrasonic multi-dectectors receivers for non destructing evaluation
Author(s): M Messaoudi, B Pouet, S Breugnot
Address: Bossa Nova Technologies, 11922 Jefferson Boulevard, Culver City, CA 90230
Abstract: New laser interferometric schemes were recently introduced and improved in order to fully take

advantage of possibilities offered by laser-based ultrasonic (LBU) inspection and to broaden their integration into industrial inspection systems and into laboratories setups. We will present the recent advances on a first LBU receiver based on multi-channel random-quadrature (MCRQ) detection. The MCRQ receiver is fiberized and well suited for industrial application such as thickness control on moving sample using zero group velocity Lamb wave resonance. The second receiver is based on two-wave mixing in photorefractive crystal and it has been improved to be able to measure simultaneously in-plane and outof-plane displacements. Thermoelastic generation on aluminium sample experiment enhances difference between both components, which opens up new prospects for ultrasound studies in the lab. Keyword Speckle, ultrasound, quadrature, two-wave mixing, interferometer, laser.

Time: 11:30-11:45
Title: SKED: Speckle Knife Edge Detector
Author(s): Samuel O Achamfuo-Yeboah, R A Light and S D Sharples
Address: Applied Optics, Faculty of Engineering, University of Nottingham
Abstract: The optical detection of ultrasound from optically rough surfaces is severely limited using a conventional setup because the detected light is speckled. We present a CMOS integrated circuit that can detect ultrasound in the presence of speckle. The detector circuit is based on the simple knife edge detector. It is self-adapting and is fast, inexpensive, compact and robust. The detector is implemented as a widefield camera with 32x32 smart pixels. We present the theory of its operation and discuss results validating the concept and operation of the device. We will also present results that show that it can work with optically rough surface finishes that have roughness (Ra) up to 2μm.

Time: 11:45-12:00
Title: Quantified visualisation of elastic wave phenomena using refracto-vibrometry.
Author(s): Rob Malkin
Address: University of Bristol
Abstract: This presentation will discuss time resolved quantitative evaluation of elastic stress waves in solid media by utilising an adaptation of the well-established laser Doppler vibrometry method. We show that the introduction of elastic stress waves in a transparent medium gives rise to detectable and quantifiable changes in the refractive index, which is proportional to stress. The method is tested for mechanical excitation at a range of frequencies in an acrylic bar. This refractometric quantification can measure internal strains as low as 1x10^{-11}. Additionally, finite element analysis is used to gauge the validity of the results. We also discuss the effect of signal integration along the laser path length. In the presented work an acrylic bar is used, this method however should be applicable to any transparent solid.

Time: 12:00-12:15
Title: Laser-based ultrasonic characterisation of Ge membranes
Author(s): Oksana Trushkevych, Vishal A Shah, Maksym Myronov, John E Halpin, Stephen D Rhead, Martin J Prest, David R Leadley, and Rachel S Edwards
Address: Department of Physics, University of Warwick, Coventry, CV4 7AL, UK
Abstract: Piezoelectric transducers and laser interferometry are used to study vibrations of a 700 nm thick and 965$\times$965 m square single crystal Ge membrane, in air and in vacuum. Ge on Si substrate is a basis for many optoelectronic devices, including sensors, photonic modulators, solar cells,and heterojunction bipolar transistors. Mechanically decoupling the Ge film from the Si substrate, producing a Ge membrane, can lead to a more rapid and higher sensitivity response in sensors, and allows adding new functionality to integrated systems. It is important to study the robustness to shock and the elastic behaviour of the membrane before building devices, and laser interferometry is an ideal method for these measurements. Resonance modes up

to 3:2 of the membrane are studied in detail both in the frequency and the spatial domain, and residual stress of the membrane, as well as the quality factors of modes at various pressures, are extracted.

3 Lunch 12:15-1:30

Lab visits possible during lunch

4 Afternoon sessions

Time: 1:30-1:55
Title: Resonant excitation of Brillouin scattering with a single nanoparticle as an opto-acoustic transducer
Author(s): Yannick Guillet[1], Feng Xu[1], Salvatore Minissale[1], Serge Ravaine[2] and Bertrand Audoin[1]
Address: [1] Université de Bordeaux, CNRS, UMR 5295, Talence F-33405 [2] Centre de Recherche Paul Pascal, CNRS, UPR 8641, Pessac F-33600, France
Abstract: We demonstrate the detection of the GHz coherent phonons generated by an optically excited single nanoparticle embedded inside a polymer thin film. We use a picosecond ultrasonics setup relying on a common femtosecond pump-probe scheme. We detect not only the breathing mode of the nanoparticle but also the coherent phonons propagating close to the nanoparticle. The latter are detected through the photo-elastic interaction. We demonstrate that the detected Brillouin scattering magnitude is enhanced when the fundamental breathing mode frequency of the nanoparticle nearly matches the Brillouin frequency of the surrounding medium at the probe laser wavelength.

Time: 1:55-2:20
Title: Picosecond ultrasonics for single-cell biology
Author(s): Thomas Dehoux[1,2], Maroun Abi Ghanem[1,2], Atef Gadalla[1,2], Omar F. Zouani[3,4], Marie-Christine Durrieu [3,4], Bertrand Audoin[1,2]
Address: [1] Université de Bordeaux, CNRS, UMR 5295, Talence F-33405, [2] CNRS, I2M, UMR 5295, F-33400 Talence, France, [3] Université de Bordeaux, CBMN, UMR CNRS 5248, F-33607 Pessac, France, [4]Université de Bordeaux, LOMA, CNRS UMR 5798, F-33400 Talence, France
Abstract: In this paper we use GHz acoustic phonons to probe the mechanical properties of single cells. We culture cells on top of a biocompatible Ti metal film. Low-energy femtosecond laser pulses are focused at the bottom of the film to a micron spot to allow single-cell investigation. The subsequent ultrafast thermal expansion launches a longitudinal acoustic pulse in Ti, with a broad spectrum extending up to 200 GHz. The acoustic pulse is transmitted to the cell owing to the cell-Ti intimate contact.

The phonon propagation in the cell is measured remotely with an ultrafast laser probe through Brillouin light scattering. This yields a direct measurement of the local stiffness and viscosity of cells. Simultaneously, the acoustic reflection coefficient at the Ti-cell interface is measured through the transient optical reflectance changes. This innovative technique offers a unique mean to investigate quantitatively cell-biomaterial interactions without fluorescent labels or mechanical contact to the cell.

Time: 2:20-2:35
Title: Optically excited and optically probed high frequency acoustic transducers
Author(s): Richard Smith, Fernando Perez, Leo Marques and Matt Clark

Address: Applied Optics, Faculty of Engineering, University of Nottingham
Abstract: The development of nanometre sized ultrasonic transducers is important for both industrial and biological applications. The small size can be important in its own right or necessary in order to generate acoustic waves with nanometric wavelengths. There are a number of potential applications of these small size transducers; ranging from sub optical wavelength acoustic imaging to embedded sensors.

In this talk, we discuss the generation and detection of high frequency acoustic waves (low GHz) using nanometre sized optical ultrasonic transducers. These devices have been modelled using a number of different techniques to allow us to understand how tuning the device structure impacts on the optical and mechanical properties. These models agree well with signals obtained from experiments on a range of different device sizes. The transducers can be used as sensors directly - by generating mechanical resonances that depend on their local environment or for remote detection of ultrasound sound generated elsewhere for example in pitch catch mode.

Time: 2:35-2:50
Title: Detection of coherent single-pass amplification of sub-Terahertz acoustic waves
Author(s): C L Poyser, A V Akimov, R P Campion and A J Kent
Address: School of Physics and Astronomy, University of Nottingham
Abstract: We describe the use of an AlGaAs p-i-n photodiode to monitor the output of a single pass acoustic amplification, SASER, device. In the current scheme, the p-i-n detector is fabricated on one side of a 150um GaAs substrate, and two GaAs/AlAs superlattices (SLs), the lower of which can be placed under an electrical bias, are grown on the other side. The lower, SASER, SL was grown to specifications which have been previously shown, using an incoherent bolometric detection technique, to provide phonon amplification [1]. Femtosecond optical pumping of the top SL generates a quasi-monochromatic sub-Terahertz acoustic wave which propagates through the gain SL and the substrate to the p-i-n diode. This is gated by a time-delayed femtosecond pulse providing high resolution coherent detection. Evidence of coherent amplification in the SASER device was observed.
[1] Beardsley, R P et al. New J. Phys. 13, 073007 (2011)

5 Coffee 2:50-3:15pm

Time: 3:15-3:30
Title: Brillouin imaging of cultured cells using picosecond ultrasonics
Author(s): Fernando Perez-Cota, Richard Smith, Kevin Webb and Matt Clark
Address: Applied Optics, Faculty of Engineering, University of Nottingham
Abstract: Ultrasound is a well-established method for the mechanical characterisation and imaging of biological tissue. At high frequencies ultrasound has the potential to offer higher than optical resolution images which could provide useful mechanical information for cell biology studies. This has inspired research on using high frequency ultrasound on tissue and cells. Picosecond laser ultrasound, uses pulsed lasers to detect Brillouin oscillations and has reached important achievements in recent years; measurements on individual living cells [1] as well as characterisation of mechanical properties on fixed cells[2]. The work we present will discuss an alternative transducer arrangement [3] applied to this technique, which is used to reduce the laser light exposure to the cells. This combined with an ASOPS instrument to reduce acquisition time, allows the measurement of 2D images of the Brillouin frequency of mammalian fixed cells to be performed in a reasonable time frame.
[1] Applied Physics Letters 93 (12) p. 123901 [2] The European Physical Journal Applied Physics 61 (1) p. 11201 [3] Journal of Physic Conference Series 278 (1) p. 012035

Time: 3:30-3:45
Title: Extending the limited aperture of all-optical planar sensor arrays used for photoacoustic imaging system.
Author(s): R Ellwood, E Z Zhang, P C Beard, and B T Cox
Address: Department of Medical Physics & Bioengineering, University College London
Abstract: In recent years, a range of ultrasonic sensor configurations have been developed to record photoacoustic (PA) signals. The Fabry-Perot (FP) polymer film sensor benefits from being able to detect using small element sizes (10'sμm) with a low noise equivalent pressure (~0.21kPa). The small element size gives benefits in terms of lateral resolution in the final image. FP sensor arrays are typically designed to be planar, for simplicity of manufacture and interrogation. However, planar sensors have a limited view of the acoustic field, so some of the waves emitted from the PA source are not recorded. The lack of a complete data set results in artifacts in the reconstructed image. Removal of these artefacts is important for image quality, and in particular for quantitative multiwavelength photoacoustic imaging, as the artefacts will change with wavelength.

In this paper we describe a new approach using a planar array and acoustic reflectors that increases the effective aperture of the detector. This results in a noticeable reduction in artefacts, increased spatial resolution and SNR compared to planar detection geometry alone. Several proposed arrangements were assessed to select the optimal configuration. Initial results from an experimental system implementing this design are reported. Practical limitations of this technique are discussed.

Time: 3:20-3:35
Title: Quantitative ultrasound-modulated optical tomography: forward models, reconstruction, and challenges
Author(s): Samuel Powell
Address: Dept. of Computer Science, University College London, London, WC1E 6BT
Abstract: Ultrasound-modulated optical tomography (UOT) is a hybrid technique which aims to recover images of the optical absorption and scattering coefficients of biological media by combining the contrast offered by near infra-red light with the spatial resolution of focussed or time-gated ultrasound fields.

Significant effort has been expended in advancing the experimental technique in UOT, but less attention has been paid to the fundamental problem that such hybrid techniques are only capable of producing quantitative images under some form of model-based reconstruction procedure.

In this presentation I will provide a perspective of requisite forward models for UOT, introduce the inverse problem, demonstrate a simulated reconstruction using a linearised diffusion style model, and discuss some of the challenges in moving towards a practical application.

Time: 3:45-4:00
Title: Theoretical and experimental evaluation of fluorophore-labeled microbubble system
Author(s): Qimei Zhang[1], Melissa L Mather[1,2], Bowen Tian[3] and Stephen P Morgan[1]
Address: [1] Electrical Systems and Optics Research Division, Faculty of Engineering, University of Nottingham, UK [2] Institute of Biophysics, Imaging and Optical Sciences, Faculty of Engineering, University of Nottingham, UK [3] School of Pharmacy, University of Nottingham
Abstract: Ultrasound modulated fluorescence tomography (USMFT) has potential to be a useful technique to obtain fluorescence images with optical contrast and US resolution in deep tissue. However, the very low modulation depth due to the intrinsic incoherent properties of fluorescence leads to low signal-to-noise ratios (SNR) and poor image contrast. To enhance the modulation depth, microbubbles (MBs), which are used regularly in diagnostic ultrasound (US) as contrast agents, can be used. At an appropriate concentration

of fluorophore the MBs self-quench. With application of US the oscillation of microbubbles changes the intermolecular spacing of the fluorophores on the MB surface and this leads to a higher modulation of fluorescence signal. This enables localised fluorescence measurements in thick tissue to be performed. Here we focus specifically on the characteristics of fluorophore-labelled MBs and identify theoretically the optimised MB size, fluorophore concentration and US pressure to obtain the highest modulation depth. Some initial experimental results using a light scattering approach will also be presented.

6 Closing remarks and prize for best paper

David Gibson of Photon Lines has kindly donated a prize for best paper which will be announced at the end of the session.

7 Lab visits

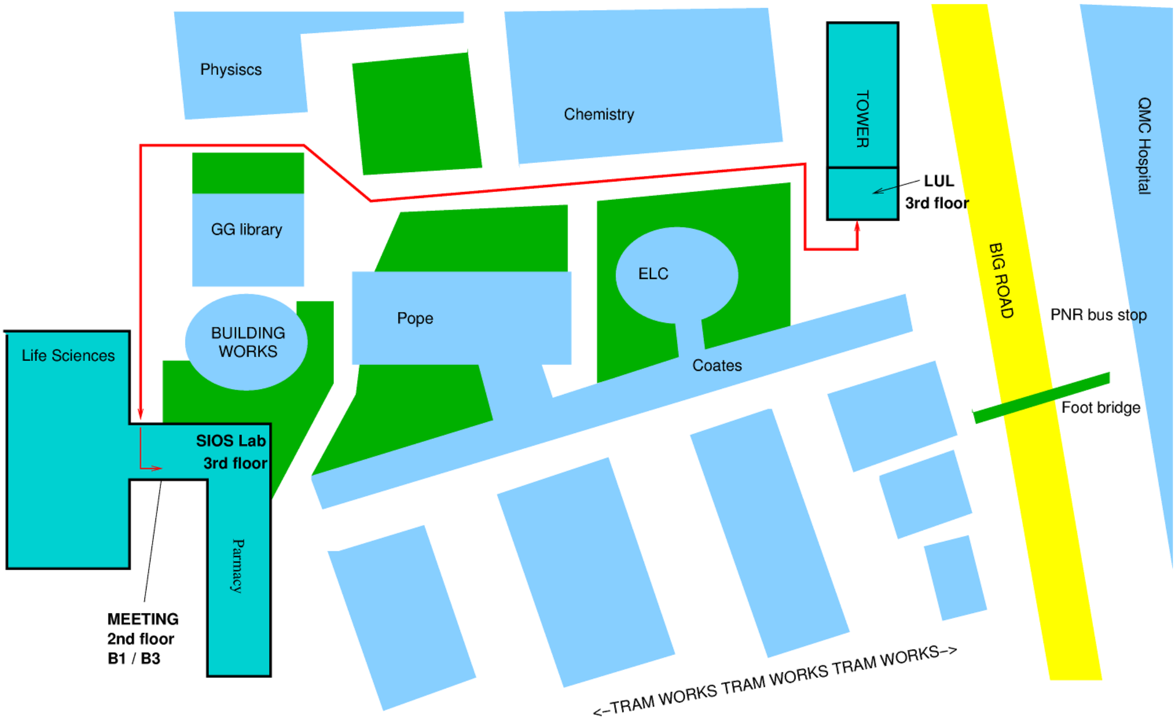
The SIOS and Laser Ultrasonics labs will be open during the day if you would like to view any of the experiments listed. In addition Photon Lines and Bossa Nova will be demonstrating their new multi detector receiver.

The following papers will have demonstrations:

Name	Title	Location
Wenqi Li	Spatially resolved acoustic spectroscopy: a laser ultrasonic technique for materials characterisation	LUL
Mikael Messaoudi and David Gibson	Recent progress in laser ultrasonic multi-dectectors receivers for non destructing evaluation	LUL
Samuel Achamfuo-Yeboah	SKED: Speckle Knife Edge Detector	LUL
Victoriya Ageeva	Cheap Optical Transducers (CHOTs) for in-situ application and ultrasonic testing	SIOS
Richard Smith / Fernando Perez	Optically excited and probed high frequency acoustic transducers / Brillouin imaging of cultured cells using picosecond ultrasonics	SIOS

7.1 SIOS and LUL locations

The SIOS lab can be found in the same building as the meeting on the third floor (turn left out of the lecture theatre, up the stairs at the end). The LUL lab can be found on the third floor of the Tower building a short walk from the Life Sciences building where the talks are held. To visit either lab please talk to one of the local organisers.



8 Maps and Travel

Maps for Nottingham and and the University can be found here:
http://www.nottingham.ac.uk/about/visitorinformation/mapsanddirections/mapsanddirections.aspx
Everything is on the University Campus (click the biggest box on the clickable map above).

The meeting and the SIOS lab are in the Life Sciences building (#23) and the LUL lab is in the Tower building (#37). Registration, lunch and coffee are in room B1 and the meeting is in B3 both on the 2nd floor.

8.1 Train

Trains for the University go to Nottingham of Beeston stations. The former more regular, the latter slightly more convenient.

From Beeston station you can either walk the 2 miles (at least the last half is quite nice), or catch a bus from Queens Road (200m from the station) going east or get a taxi (0115 9607607 is a reliable taxi firm).

From Nottingham station it is about 2.5 miles and while it is possible to walk into town and catch a bus (34 from Angel Row or any bus to the QMC) it is probably simpler to get a cab. Note the station is being rebuilt and has tram works so expect a little chaos and allow a little more time than usual.

8.2 Driving

It is not an exaggeration to say that parking at the University is very difficult, especially at the moment with significant road and car park closures while a new tram line is being built through the main campus.

If you are intending to drive then the best option is to drive to the Queen's Drive Park and Ride (post code NG2 1AP) and catch the Medilink bus to the campus. It is free to park and free to ride the bus. The bus goes every 10 minutes and the journey takes 10-15 minutes. The last bus back is at 18:25 (or a 1 mile walk) but the site closes at 8:30pm.

You need to get on/off at the Medical School bus stop. You then need to cross the main road using the green footbridge. The Medilink timetable and map can be found here: http://tinyurl.com/k5vmxyj

It is about a 10 minute walk from the bus to the Life Sciences building where the talk are to be held.

NB: there are big roadworks from J24 of the M1 to Nottingham which has made journey times to Nottingham from J24 or J25 longer than usual.

9 Contacts

If you need to contact us urgently on the day please email Harsha Brooks `Harsha.Brooks@nottingham.ac.uk` or ring 07988885770.