The Royal Academy of Engineering

Senior Research Fellowship

Development of Mid-Infrared (IR)-Transmitting Optical Fibre Devices & Systems for Applications in Medical Surgery, Diagnosis & Imaging

Funded by The Leverhulme Trust

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1) Introduction

We propose using mid-infrared (IR) light for medical laser surgery and *in vivo* diagnosis & imaging.

Practical deployment requires the means to generate mid-IR light & route it to where needed.

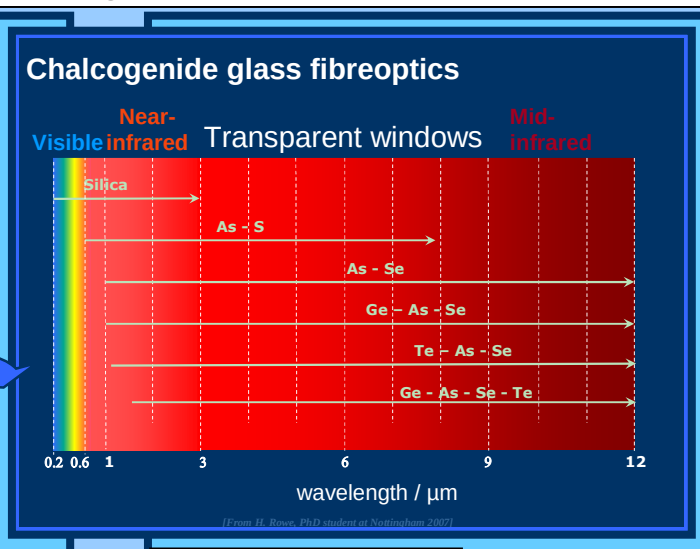
Conventional silica glass fibreoptics are opaque to mid-infrared light.

We are developing mid-IR-transmitting, chalcogenide-glass, fibreoptic devices which are functionally designed, safe & cost effective for medical surgery, diagnosis and imaging.

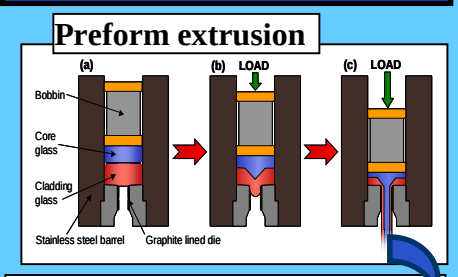
2) Research objectives

(1) flexible fibre delivery for CO_2 laser ablation surgery
(2) medical diagnostics by means of surface tissue spectral evaluation for possible cancer screening
(3) powerful narrow- & broad-band mid-IR sources for surface tissue imaging & laser surgery.

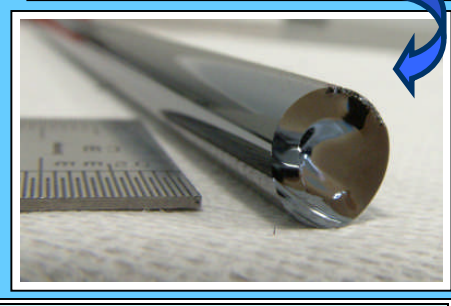
Longer term objectives: development of mid-IR endoscopy for internal tissue surgery, diagnostics and imaging.



3) Making low loss preforms & fibre

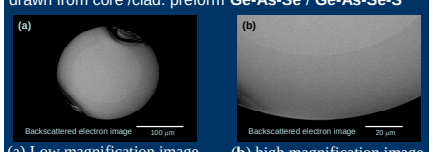


Fibre-drawing



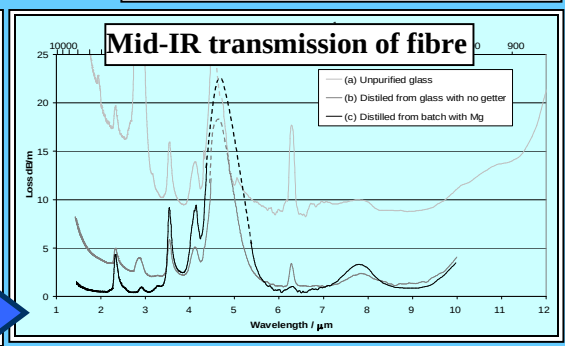
Microscopy results of fibre drawn from core/clad. co-extruded preform

ESEM images of cross-section of fibre taken from 55-57 m drawn from core /clad. preform **Ge-As-Se / Ge-As-Se-S**



(a) Low magnification image (**b**) high magnification image

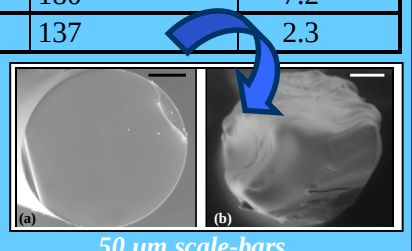
No defects observed



4) Laser power delivery

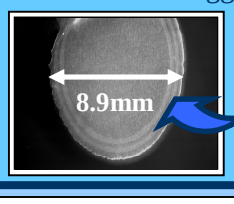
Fibre core/clad? Glass compositions?		Glass transition temperature (Tg) /°C	Optical loss/dBm^{-1} at 10.6 µm
Core Clad	$Ge_{17}As_{18}Se_{65}$ $Ge_{17}As_{18}Se_{62}S_3$	236	10.3
Core	$As_{40}Se_{60}$	180	7.2
Core	$Te_{20}As_{30}Se_{50}$	137	2.3

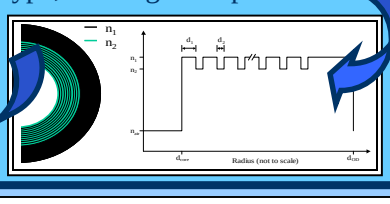
Damage tolerance of fibres was tested with CO_2 laser: 50 mW, 15 Hz, pulse-width 50 µs. $Te_{20}As_{30}Se_{50}$ did not survive due to low Tg.



50 µm scale-bars

Fibre losses still too high. Thus are developing low-loss, Bragg hollow-core fibre. Here we report, for the first time, fabrication of a Bragg-type, chalcogenide preform.



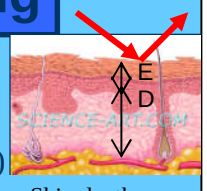


5) Mid-IR diagnosis & imaging

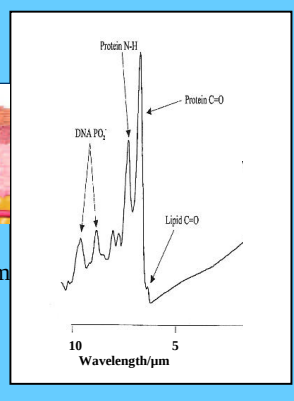
"I'll risk skin cancer for a good tan"

Skin cancer *p.a.* in UK:

- 50-100 x 10^3 cases of non-Malignant Melanoma (MM)
- >7000 cases MM - ~1700 deaths
- Incidence set to double in next 10 years.



Skin depth
E = Epidermis 5-100 µm
D = Dermis 0.25-4 mm

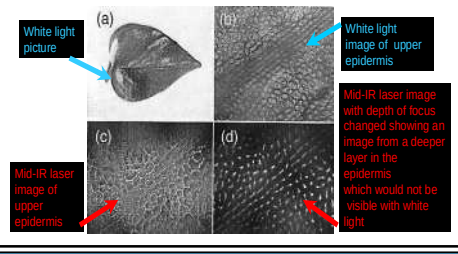


For diagnosis, mid-IR light reflected (→) from tissue (*e.g. skin)* is rich in characteristic tissue vibrational signatures. An optical system is being designed to take advantage of this.

In vitro experiments (McIntosh *et al.* 2001) indicate good mid-IR-spectroscopic discrimination between normal human skin, benign and malignant tumours.

For mid-IR imaging, microstructured fibres for broadband supercontinua generation sources & rare-earth-doped, mid-IR fibre lasers are being designed & developed.

Infrared micro-reflectance 3-D imaging of house plant leaf (*Epipremnum Pinnatum)* using mid-infrared lasers.
Guo et al. 2004 **Currently such lasers are not readily available, unwieldy, expensive & mainly home-built at Lucent, USA**



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