More Than Meets the Eye, Light through Active Glass

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Optoelectronics Research Centre

Southampton University Photonics Day

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Outline

- What is a Chalcogenide Glass?
- Raw Materials & Glass Compositions
- Current Research
- New Directions

The Chalcogenides

What is a Chalcogenide?

- From Greek *sulphur-loving* for elements that frequently bond to sulphur
- Seen in various forms: crystalline, single crystal, quantum dots, phosphors, ceramics

Typical Amorphous Compositions

- As-S, As-S-Se, Ge-Sb-Te
- Predominately As or Se based

ORC Research Focussed On

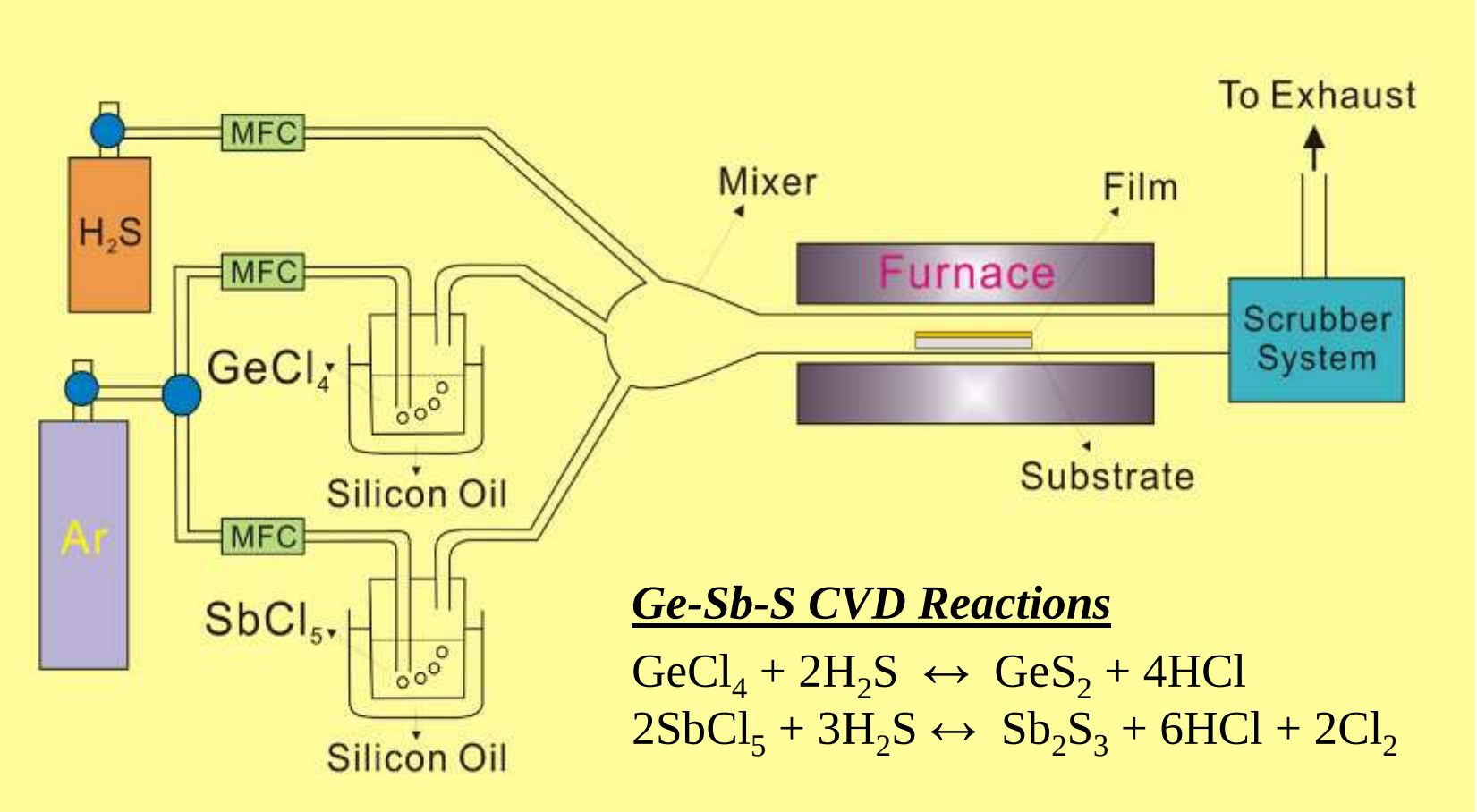
- Gallium Lanthanum Sulphides
- Germanium Sulphides
- With Many Other Explored

Glass Fabrication

- Raw Materials batched in nitrogen purged glove box
- Gallium and lanthanum sulphides melted in vitrous carbon crucibles
- Typically 24 hours at 1150^{o}C
- Rapidly quenched to below glass transition temperature
- Annealed at 500^{o}C, depending on ingot size

With Thanks to David Kinnison, Mark Weller and Alisdair Douglas, School of Chemistry

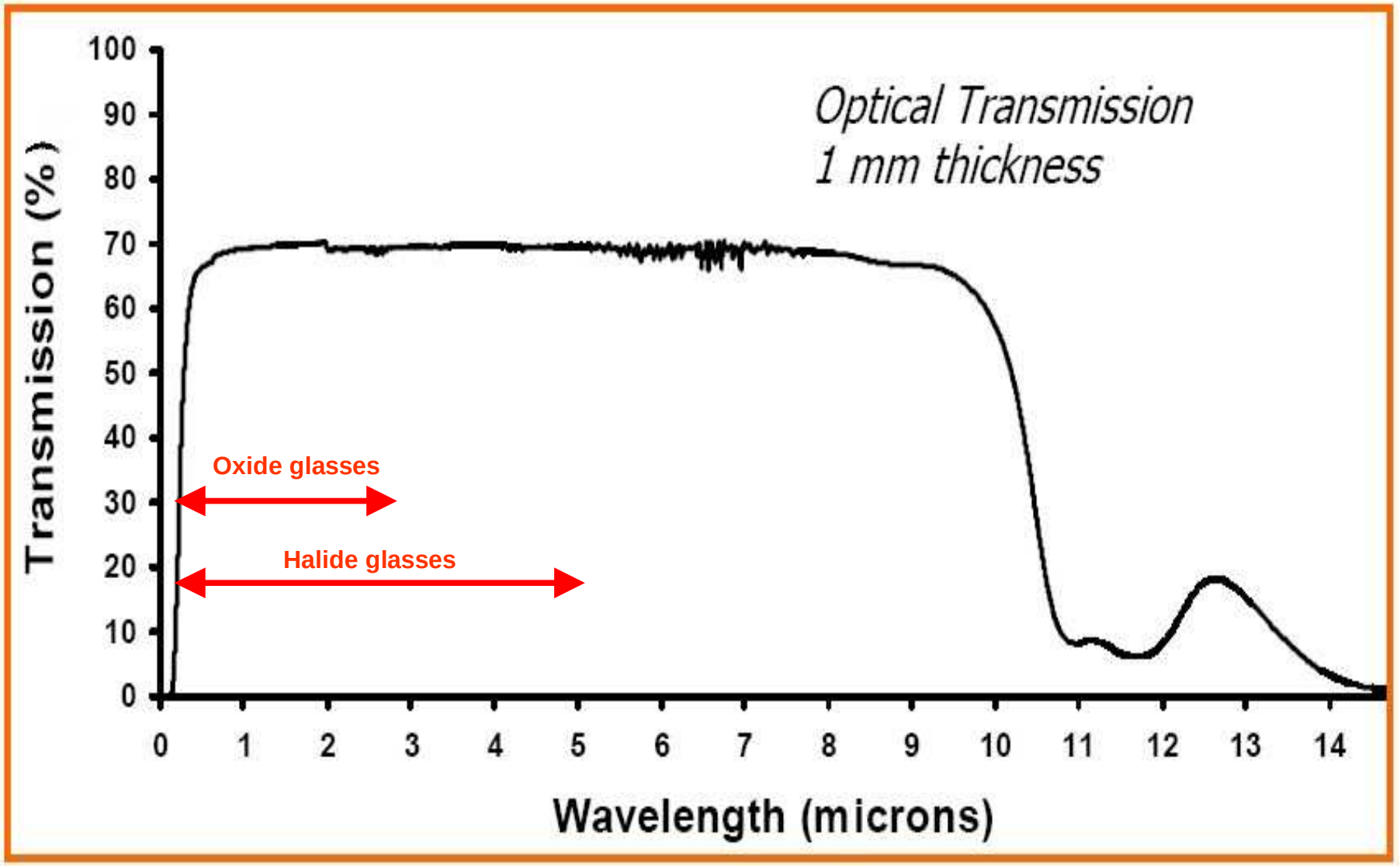
Chemical Vapour Deposition of Chalcogenides



Apparatus for Ge-S and Ge-Sb-S glass thin film and bulk glass fabrication

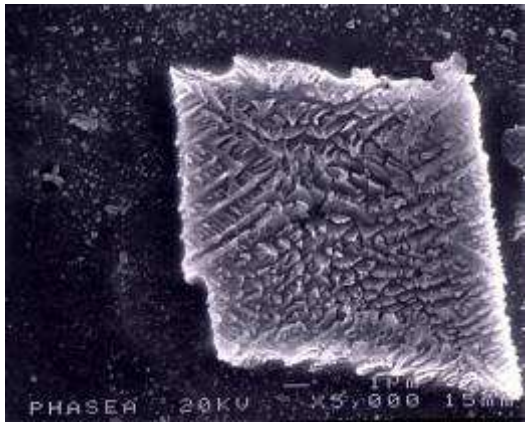
Kevin Huang, Kenton Knight with thanks to Ed Weatherby and Neil Fagan

Basic Properties - Optical



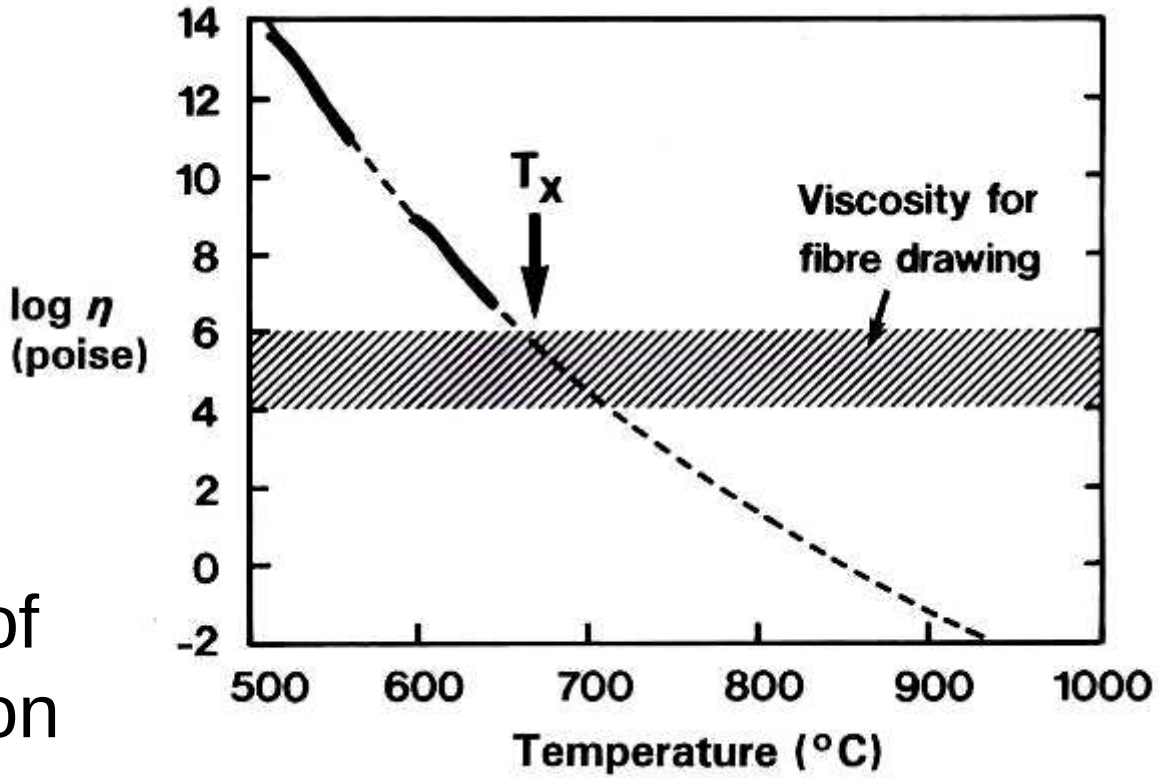
Wavelength (μm)

Basic Properties - Thermal



SEM by M Petrovich

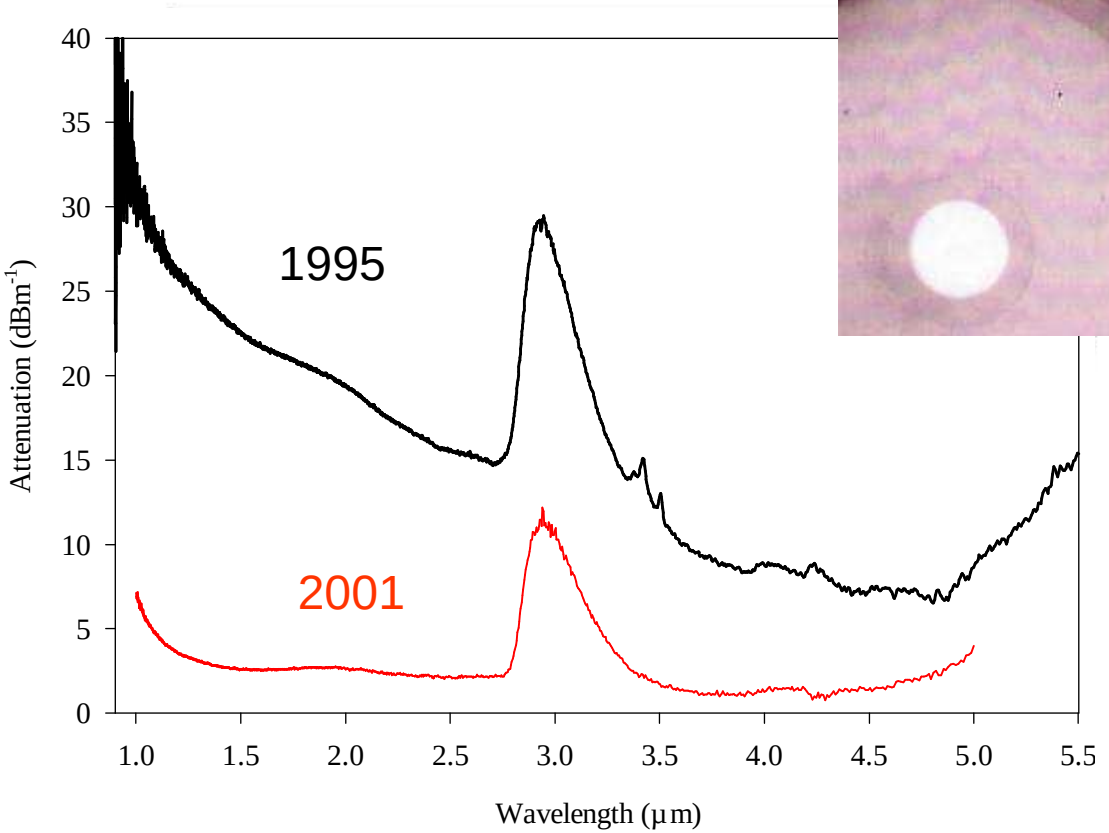
$Ga_3La_{10/3}S_{12}O_2$ crystallized in the tetragonal (melilite) structure

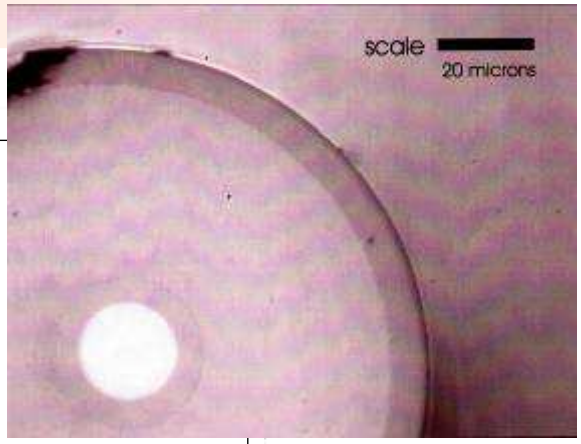


T_x is the onset of crystallization

Raw Material Purification

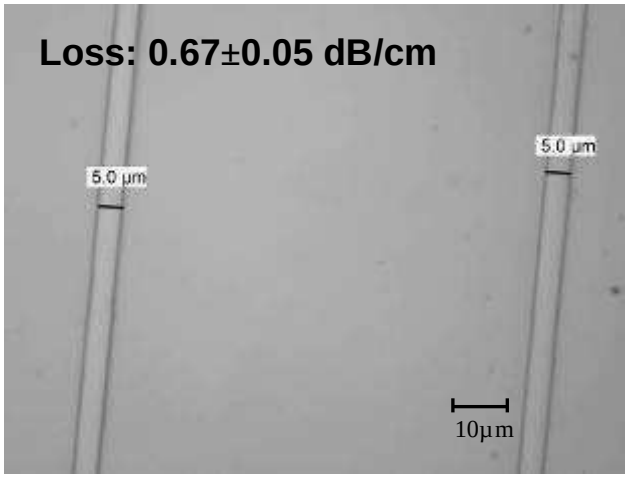
Optical Fibre Attenuation





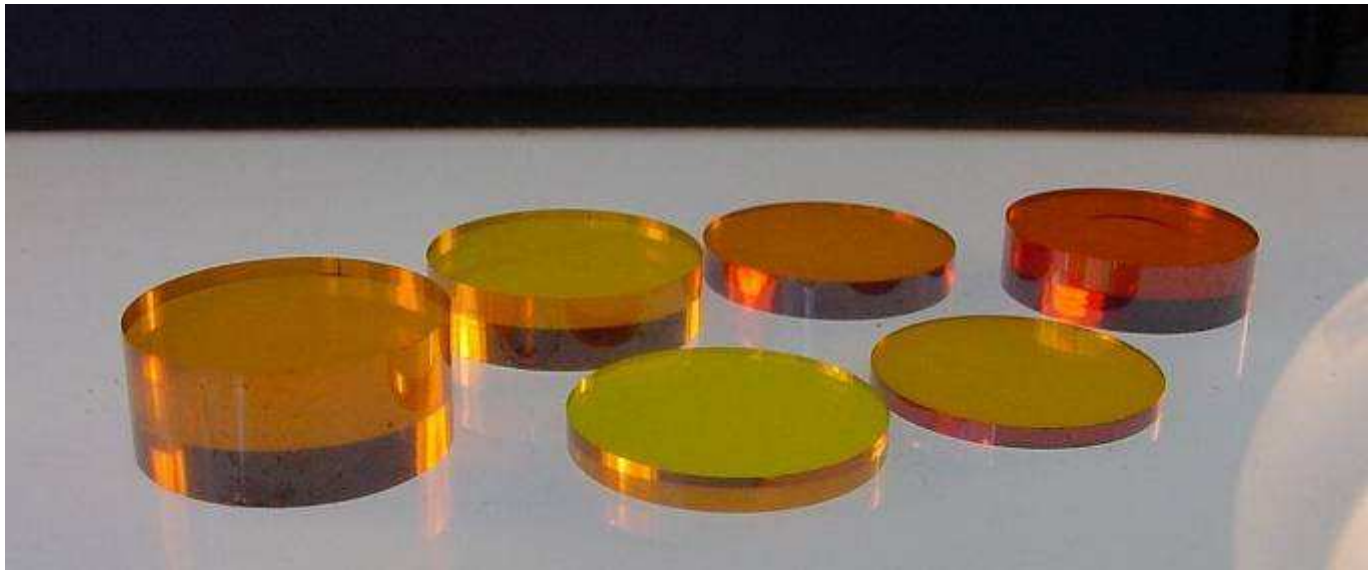
- LaC = Lanthanum Sulphide produced in-house
- Impurity content (ppm) measured with GDMS (Glow Discharge Mass Spectrometry)
- Gradual reduction of Fe impurities mirrors overall purity improvements

Integrated Optical Circuits



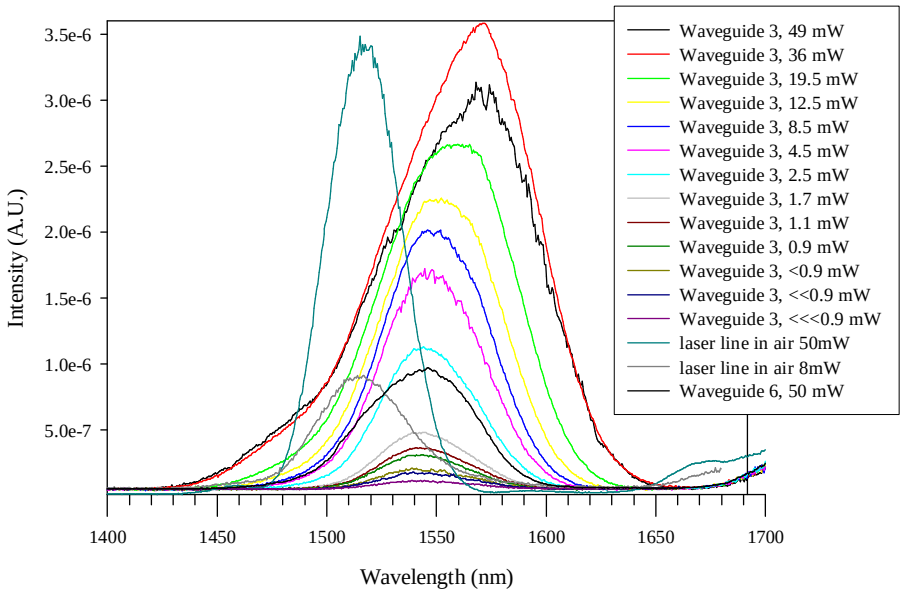
- Silver diffused channel waveguides in $GeS_{1.6}$ glass
- Fabricated by photolithography, thermal evaporation and a photo-dissolution process

Kevin Huang



Nonlinear Effects

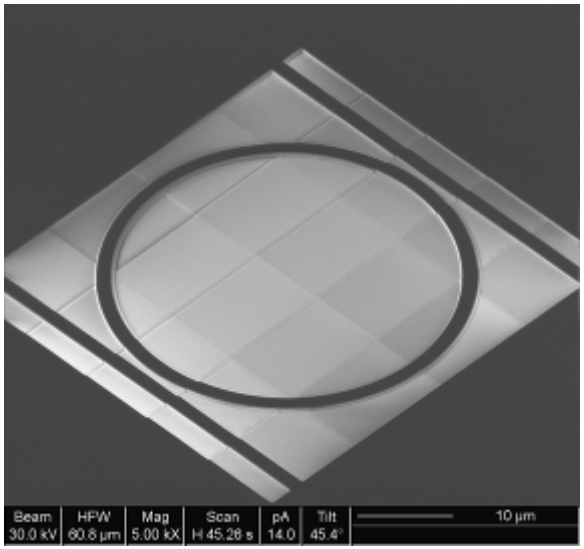
Spectral Broadening in
GLSO Buried Waveguides



Spectra of 1520 nm fs pulses through 15 mm waveguide

Mark Hughes with FAST Facility

Ge-Sb-S ring resonator on
15µm SiO_2/Si wafer



Fabricated by CVD and by FIB in with University of Bristol

Greg Elliott and Kevin Huang

Microspheres

Mag = 28 X

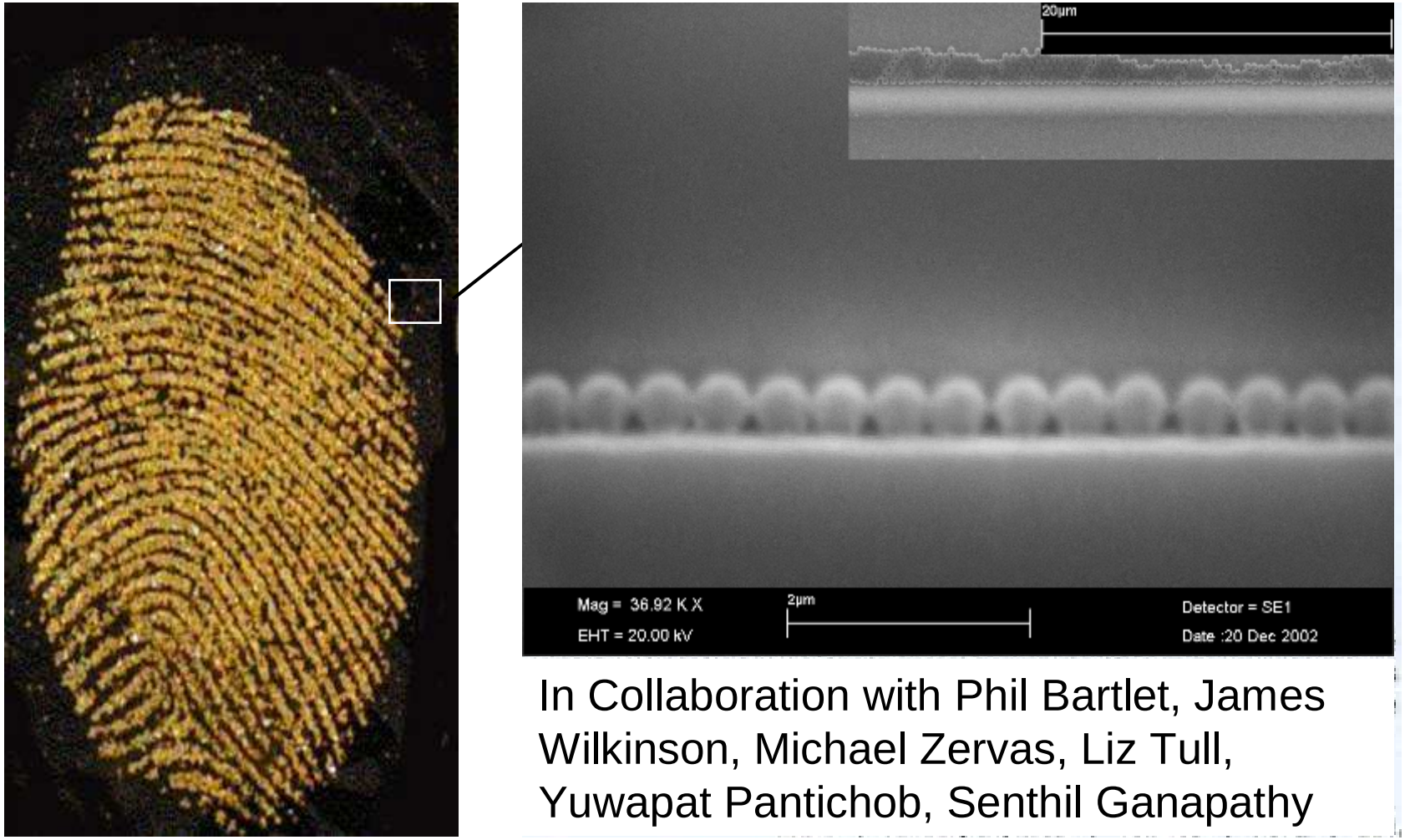
EHT = 20.00 kV

2mm

Detector = SE1

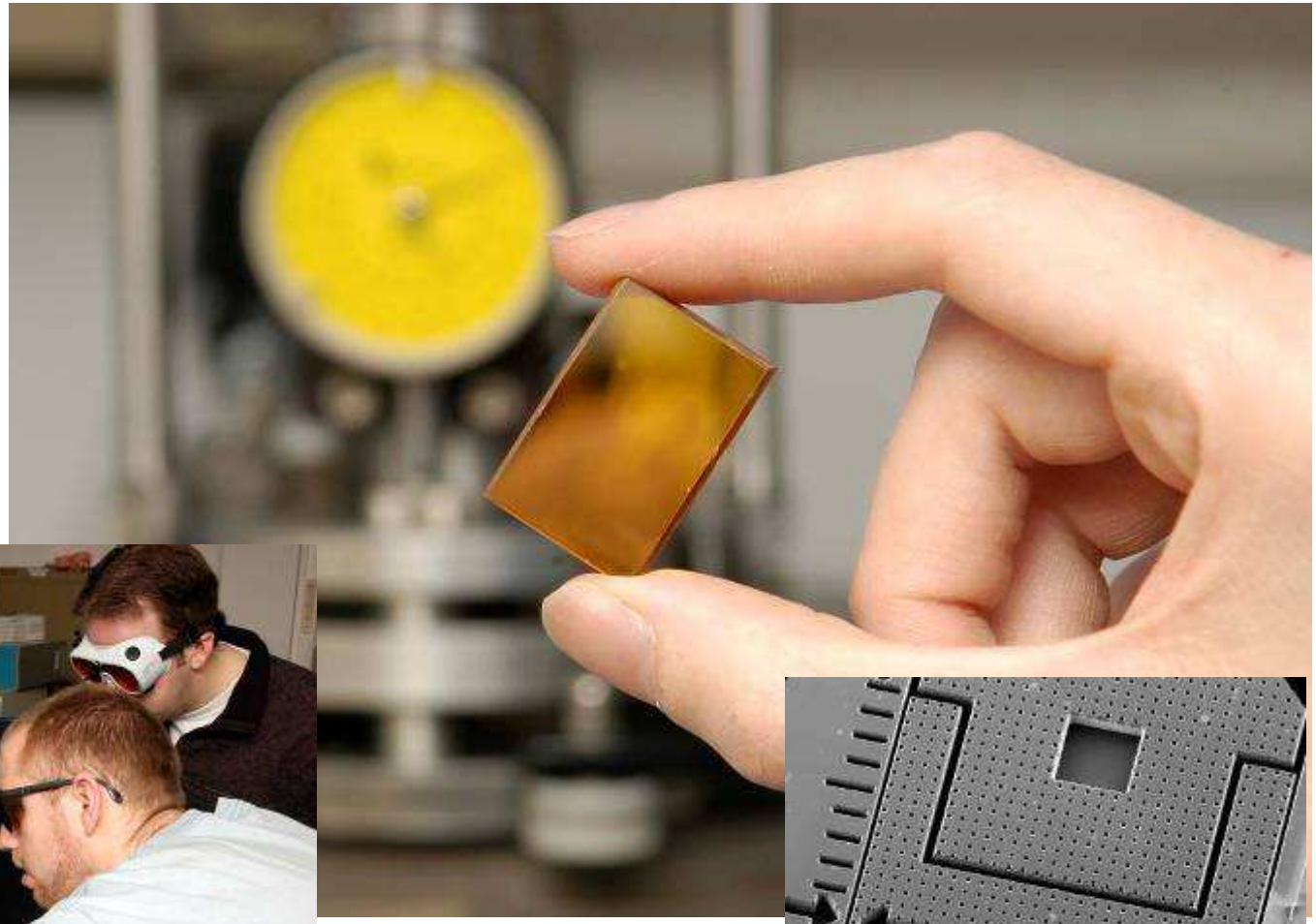
Date :10 Aug 2005

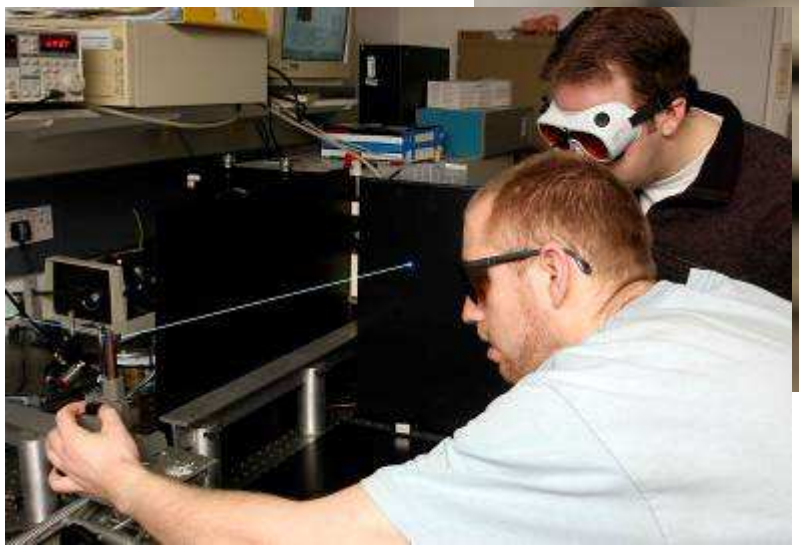
Exploiting Microspheres



In Collaboration with Phil Bartlet, James Wilkinson, Michael Zervas, Liz Tull, Yuwapat Pantichob, Senthil Ganapathy

What Next?





Microsphere Lasers

- Demonstrated elsewhere in silica, fluoride and phosphate glass
- Characterized by extremely low thresholds (200 nW reported)

Characteristics:

- Phosphate glass
- 50 – 300 micron diameter
- Dopant 20% Yb and 0.5% Er
- 60 µW threshold
- Single mode at 1.5 microns
- Sphere to fibre coupling

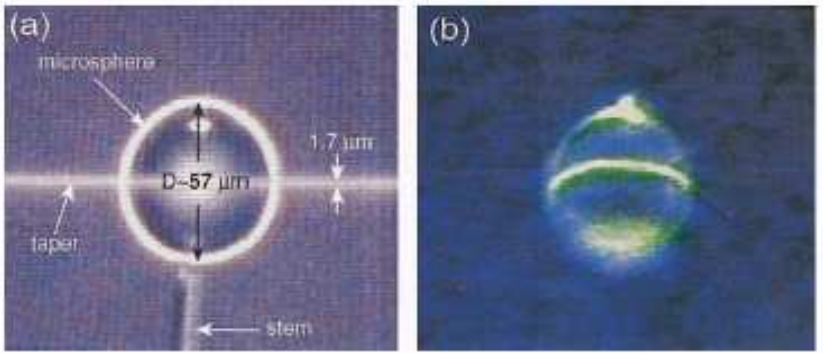


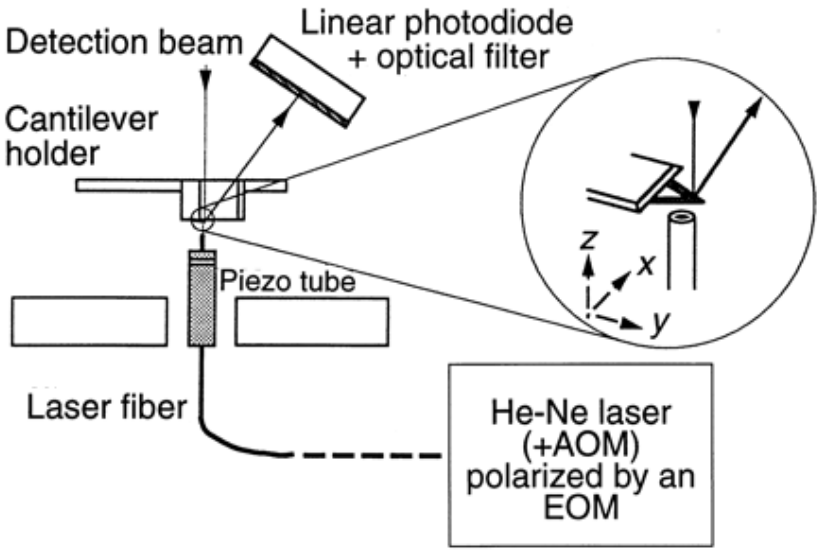
Fig. 1. (a) Image of the taper in contact with the equator of the microsphere. (b) Color image of the green upconverted photoluminescence from the taper-pumped microsphere, where the pump wavelength is tuned close to a fundamental ($|m| = l$) WG mode.

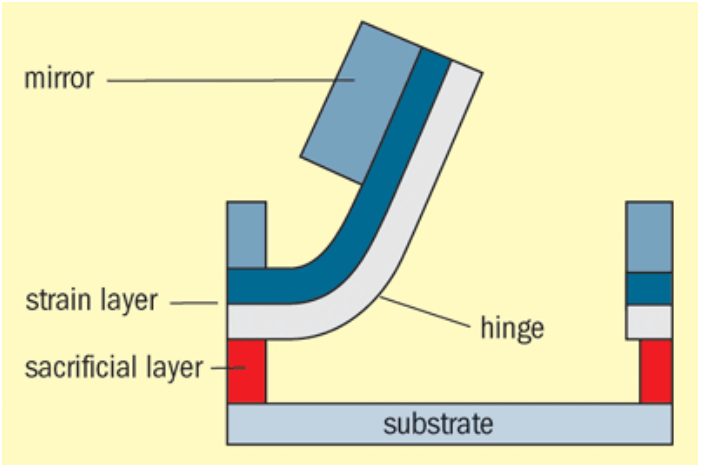
Cai et al,
Optics Letters Vol. 25 p.1430 (2000)

Photo-Mechanical Devices …

“Illuminated materials bend, curl and move”

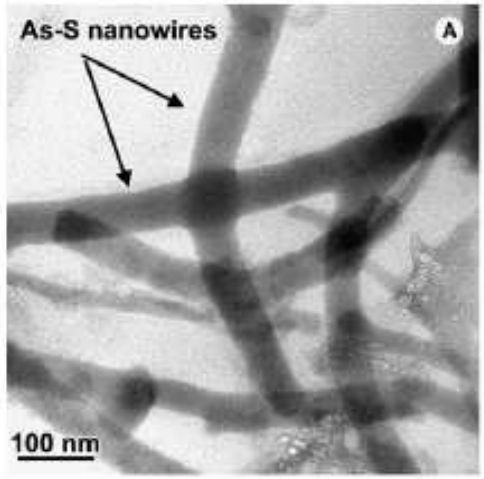
- **Demonstrated in As-S-Se glasses**
- **Contraction parallel to the direction of the light's polarization**
- **Fully reversible, maximum deflection for a 380μm cantilever was 6.5μm**
- **X-ray analysis, suggests stress is induced inside the glass on illumination**
- **Response time is less than 100μs**





Stephen Elliott,
University of Cambridge (2005)

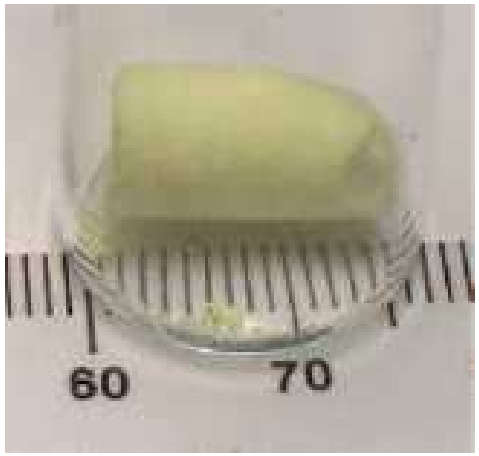
Emerging Nanostructures …



Chalcogenide Nanowires

- Synthesized from As_2S_3 by evaporation – condensation
- Diameters ranging from 40 to 140 nm, lengths several mm
- Nanowires are amporphous and stoichiometric

Bradley Johnson et al,
Pacific Northwest Laboratory (2004)



Chalcogenide Aerogels

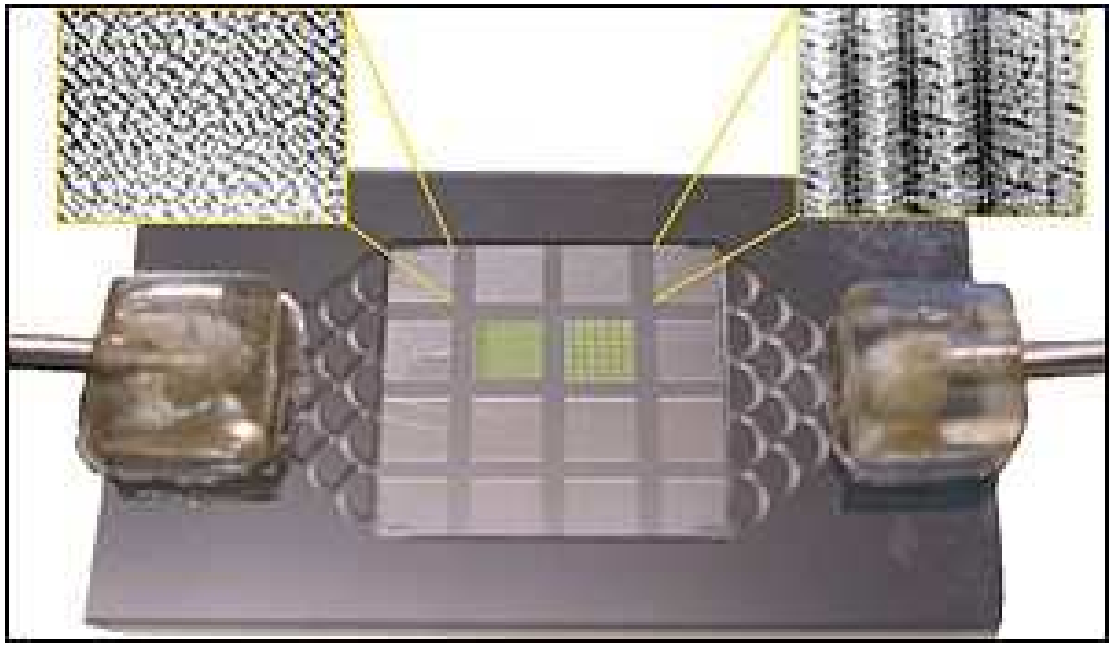
- Fabricated by sol-gel from ZnS, CdS and CdSe
- Mesopores 2 to 50 nm present, crystalline architecture
- Potential for photovoltaic and sensing applications

Jaya Mohanan et al,
Wayne State University (2006)

The Electronic Tongue

Chalcogenide films taste" liquids through ionic, redox or molecular interactions

Accurately measuring alcohol, pH, tartaric acid content, conductivity and more



Prototype developed at the University of Rome, based on 29 individual sensors, distinguishes between different samples of mineral water and wine.

Summary

❖ From a foundation based on high purity glass, extensive characterization and diverse fabrication techniques, a wide and varied research programme has developed.

❖ Chalcogenide glass bridges the gap between traditional glass and semiconductors, offering diverse applications, many still to be exploited.

❖ Watch for this glass in your next iPod or wine tasting !

Thank you !