Experimental methods I

Example experimental set ups and methods

M.P. Vaughan

UCC

Example experimental setup (1)

UCC

- Set up to investigate the dynamics of laser pairs (mounted on the same chip) subject to mutual optical injection
- Acronyms used:
  - DBR – Distributed Bragg Reflector (laser)
  - TEC – Thermo-Electric Controller
  - FPI – Fabry Perot Interferometer
  - ESA – Electrical Spectrum Analyser
  - OSA – Optical Spectrum Analyser

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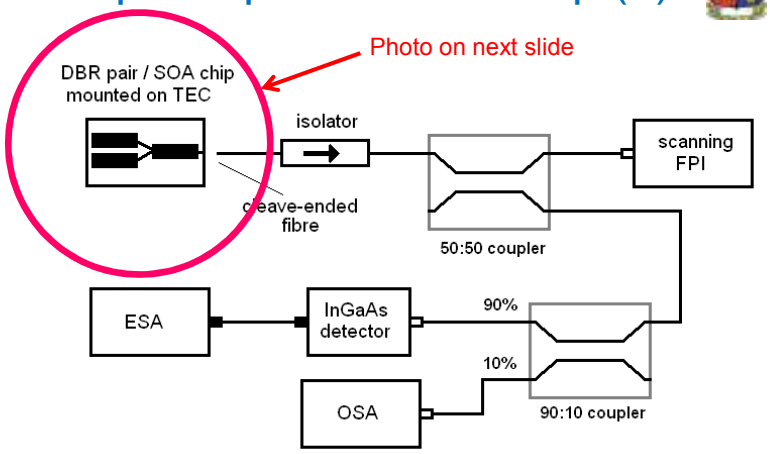
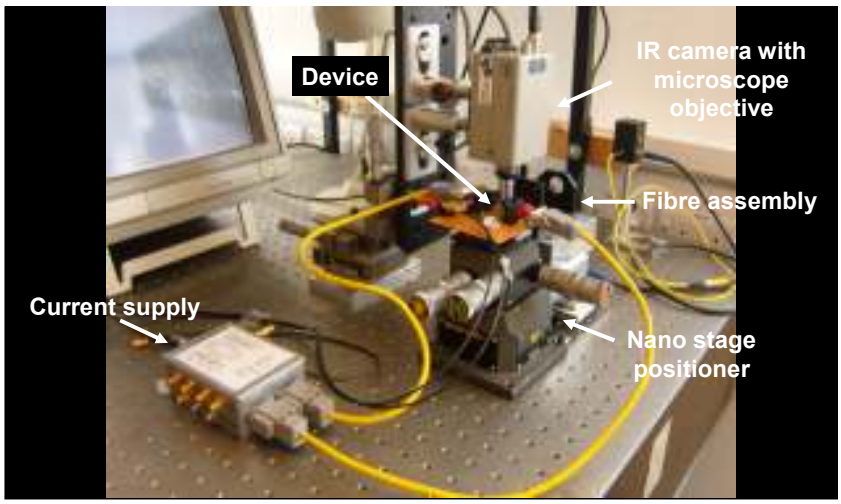
Example experimental setup (1)

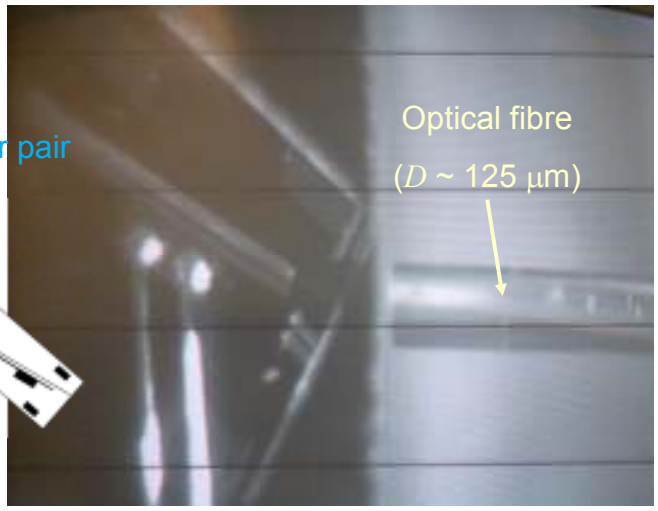


Schematic of the experimental setup for the mutual injection measurements.

Laser mounting



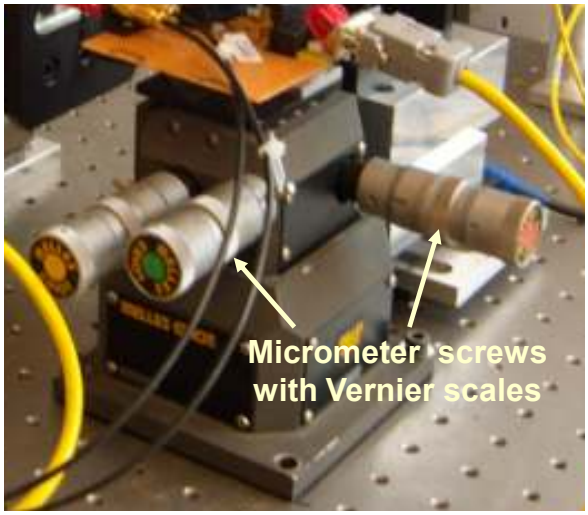
Fibre coupling to semiconductor laser



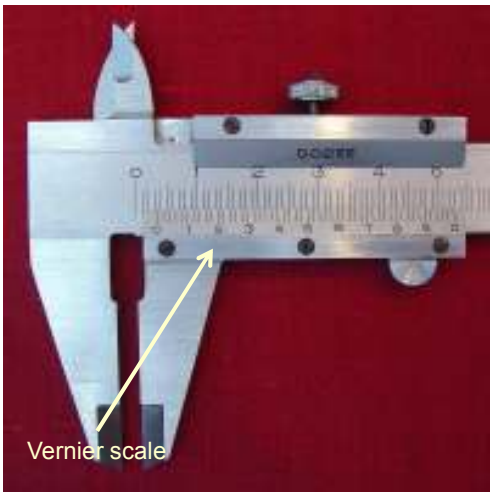
Elements of experimental set up

- Positioners
  - Translation stages (x, y & z)
  - Rotation stages
  - Tilt stages

Nano-stage positioner

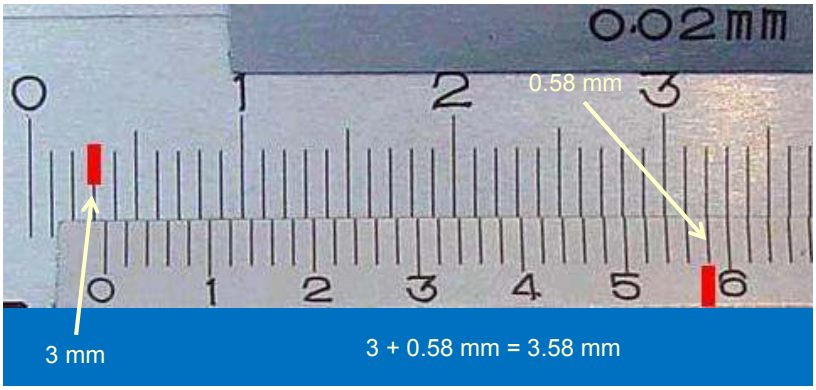


Vernier scale



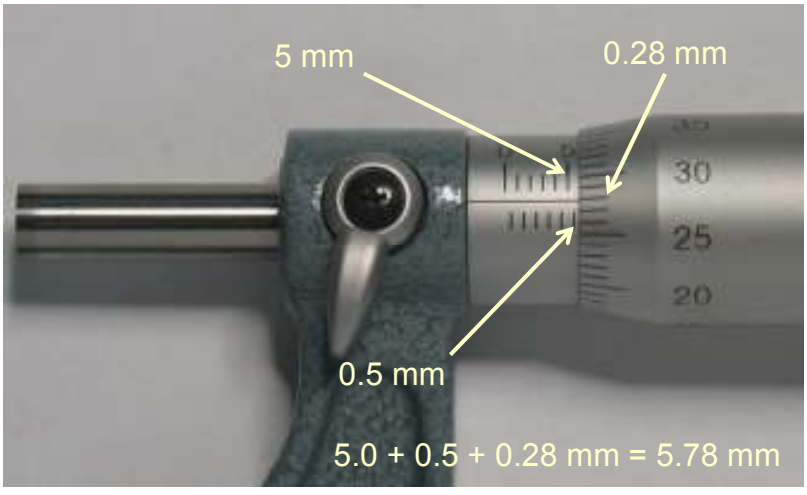
Photograph of a Vernier caliper. Copyright ArtMechanic (2004)

Vernier scale – close up



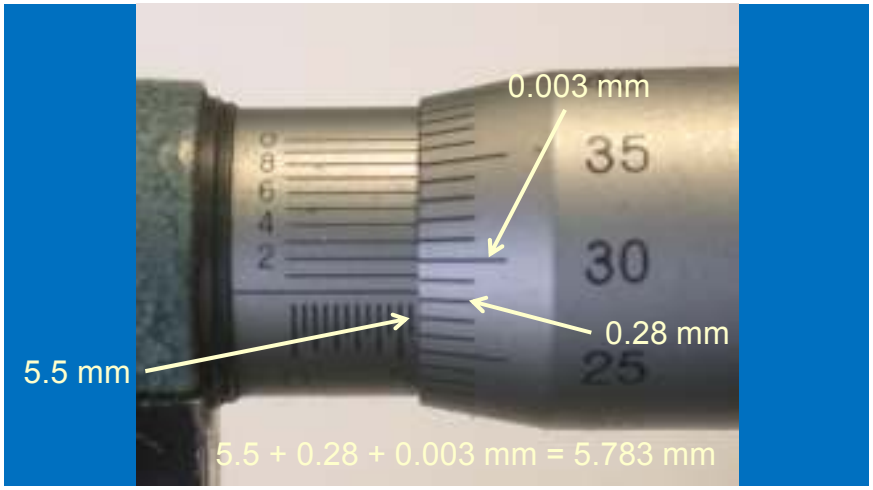
Close-up of a Vernier scale. Copyright Glenn (2005)

Micrometer – metric scale



Photograph of a micrometer. Copyright Glenn McKechnie (2005)

Micrometer – Vernier scale



Photograph of a micrometer. Copyright Glenn McKechnie (2005)

Elements of experimental set up

- Laser peripherals
  - Current source
  - Temperature controller (in conjunction with a thermistor)

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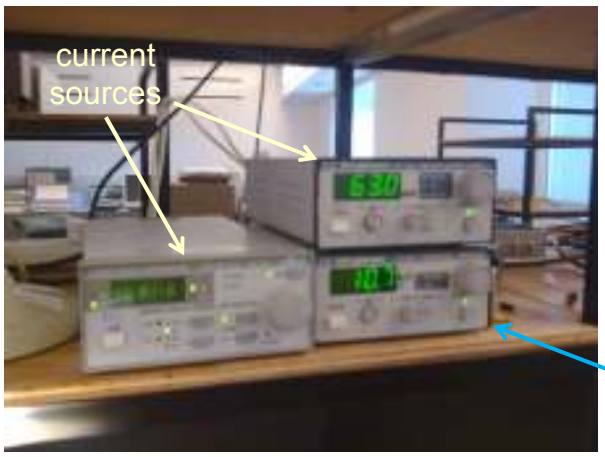
Laser peripherals



Thermistor
(resistance varies
with temperature)

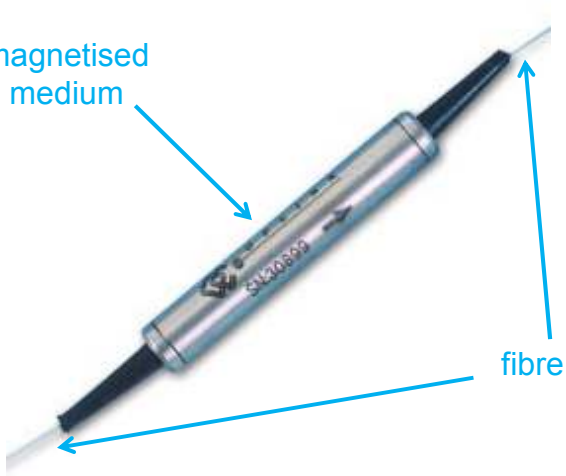
Thermo-
Electric
Controller

N.B. Thermistor generally needs to be calibrated

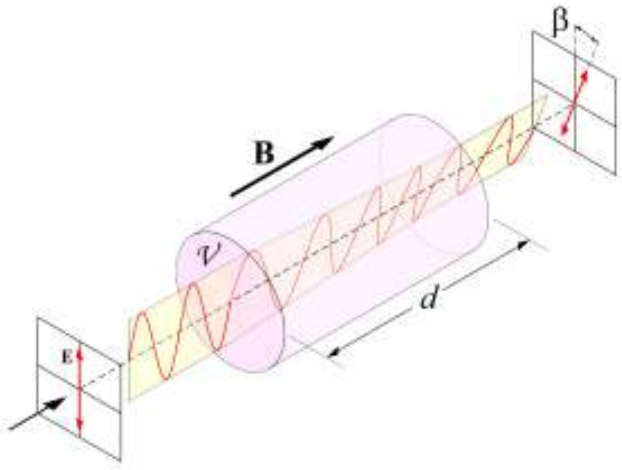
Elements of experimental set up

- Fibre optics
  - Optical fibre
  - Lens-ended fibre (for coupling laser light)
  - Optical isolator (an optical ‘diode’)
  - Polarisation controllers (‘bunny ears’)
  - Couplers (coupling / splitting light from fibre)

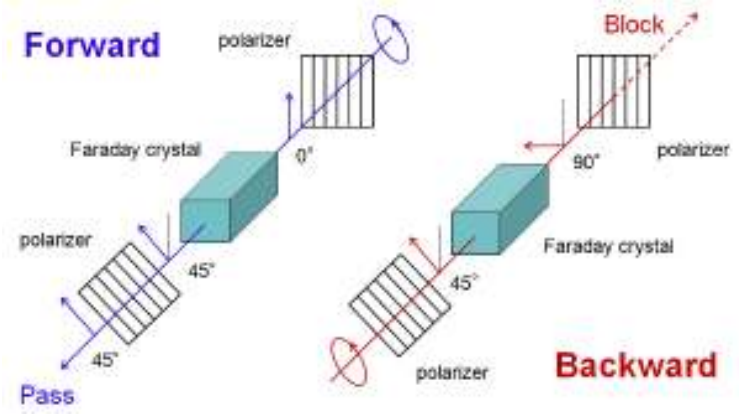
Optical isolator



Optical isolator - Faraday rotation

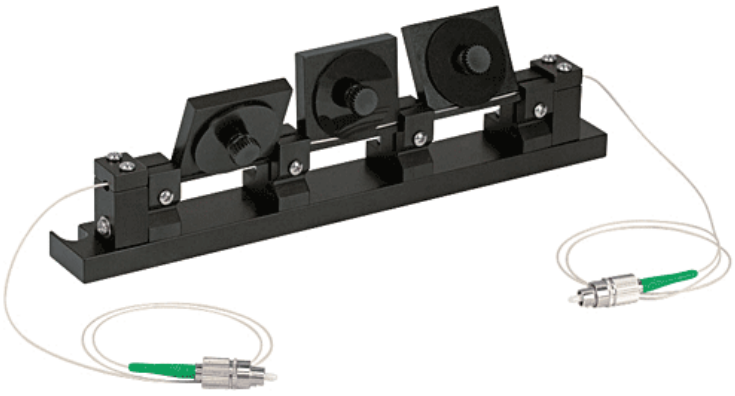


Optical isolator - Faraday rotation



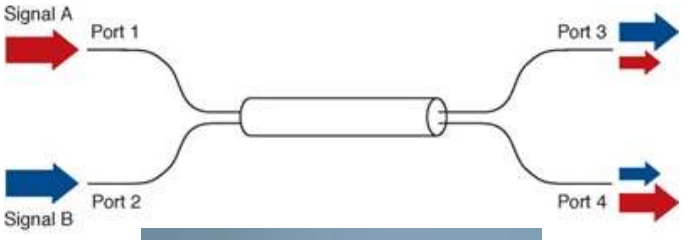
T. Amemiya and Y. Nakano (2010). Single Mode Operation of 1.5-μm Waveguide Optical Isolators Based on the Nonreciprocal-loss Phenomenon, Advances in Optical and Photonic Devices, Ki Young Kim (Ed.), ISBN: 978-953-7619-76-3, InTech, DOI: 10.5772/7143. Available from: http://www.intechopen.com/books/advances-in-optical-and-photonic-devices/single-mode-operation-of-1-5-micro-m-waveguide-optical-isolators-based-on-the-nonreciprocal-loss-phe

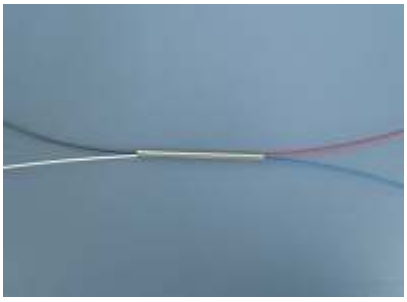
Polarisation controller ('bunny ears')



Twisting the fibre creates strain-induced **birefringence** in the fibre (light polarised in different directions travels at different speeds). The lengths of loops on the 'bunny ears' are chosen to reproduce the effect of **wave plates**.

Fibre couplers





Elements of experimental set up

- Optical analysis
  - Scanning Fabry Perot Interferometer
  - Optical Spectrum Analyser
  - Electrical Spectrum Analyser
    - In conjunction with a fast photodiode
    - Often termed an RF (radio frequency) analyser

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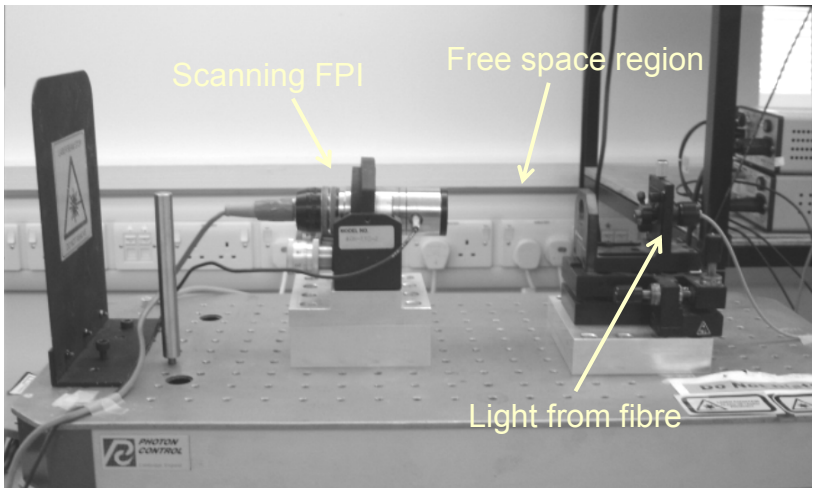
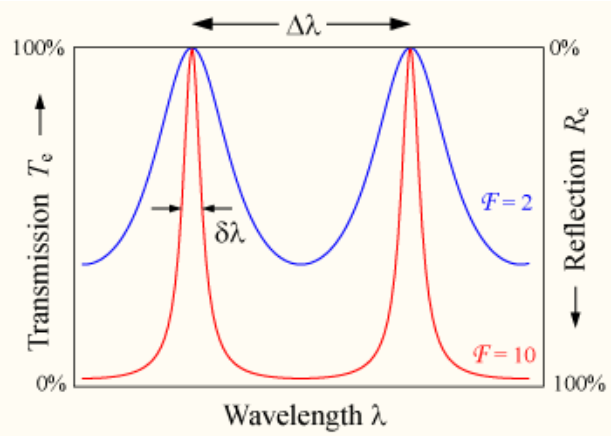
Scanning Fabry-Perot Interferometer



Scanning Fabry-Perot Interferometer

The FPI is a resonant cavity that may be used to measure the line-width of a laser.

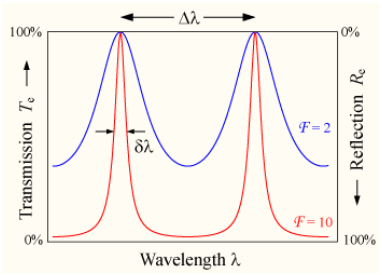


Scanning Fabry-Perot Interferometer

$\Delta\lambda$ is the **full spectral range**

$\delta\lambda$ is the **full width half maximum** of the FPI

F is the **finesse** defined by



$$F = \frac{\Delta\lambda}{\delta\lambda}.$$

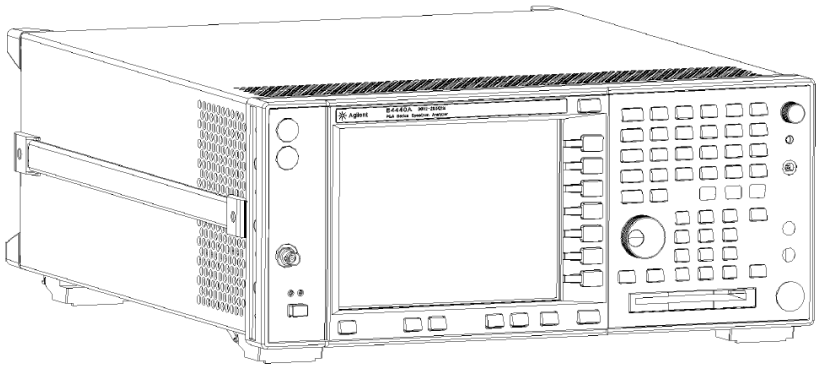
Note that $\delta\lambda$ must be less than the line-width of the laser to be measured.

Optical spectrum analyser

Optical spectrum analyser

- Usually employs a **diffraction grating** to resolve different wavelengths
- Not as accurate as FPI for line-width
- Better for measuring wavelength / frequency over design ranges (usually optical to IR)

Electrical (RF) spectrum analyser



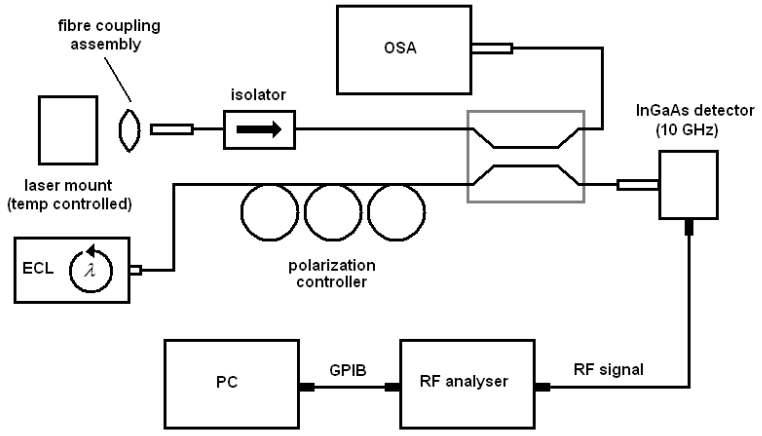
Performs a Fourier analysis of the electrical input signal

Example experimental methods

- Measuring laser line-width
  - Heterodyning
  - Self-heterodyning

Heterodyning set up

2 laser heterodyning set up



N.B. ECL – External Cavity Laser

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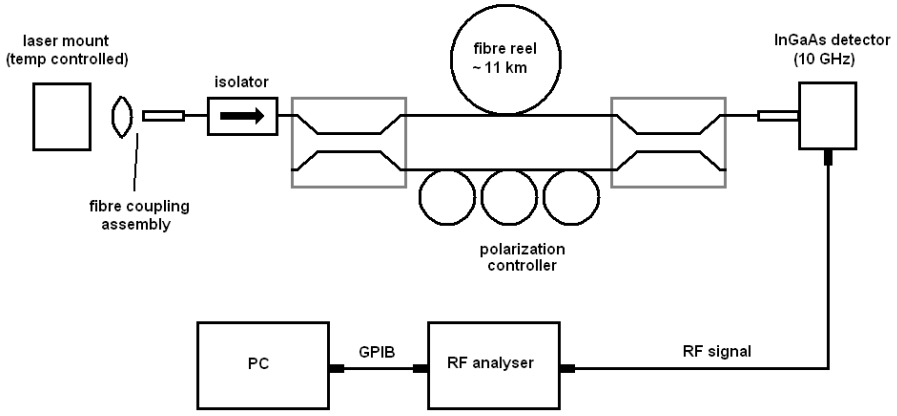
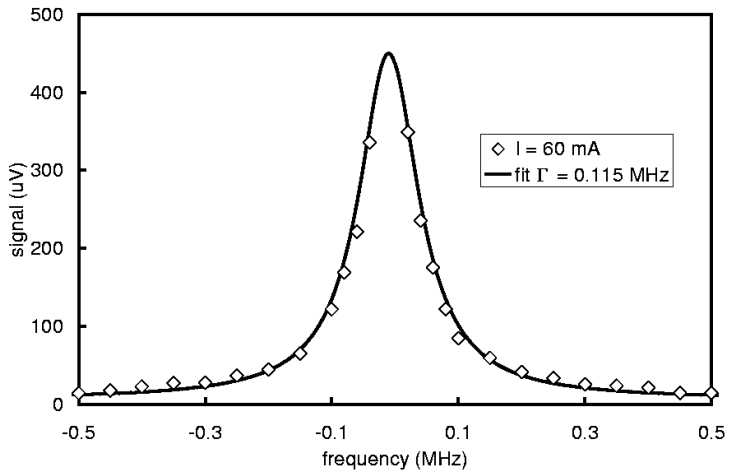
Self heterodyning set up

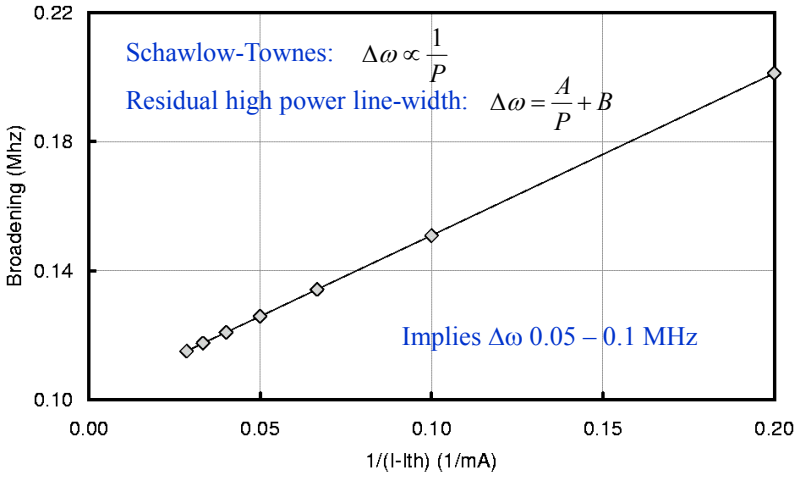
Self-heterodyning set up



Line-width of ECL via self-heterodyning



Line-width of ECL via self-heterodyning



Example experimental setup (2)

- Investigation of novel THz devices based on photomixing
- Uses some of the same equipment for the mutual optical injection measurements
- Further acronyms:
  - DFB – Distributed FeedBack (laser)
  - EDFA – Erbium Doped Fibre Amplifier (optical amplifier)

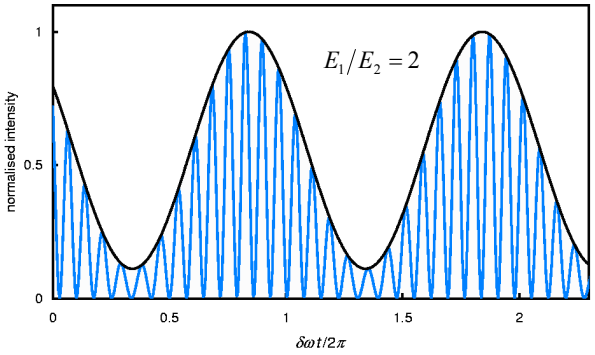
Photomixing

Mixing of two de-tuned optical sources

$$E = E_1 e^{i\omega_1 t} + E_2 e^{i\omega_2 t + \phi},$$

where

$$\omega_1 - \omega_2 = \delta\omega$$

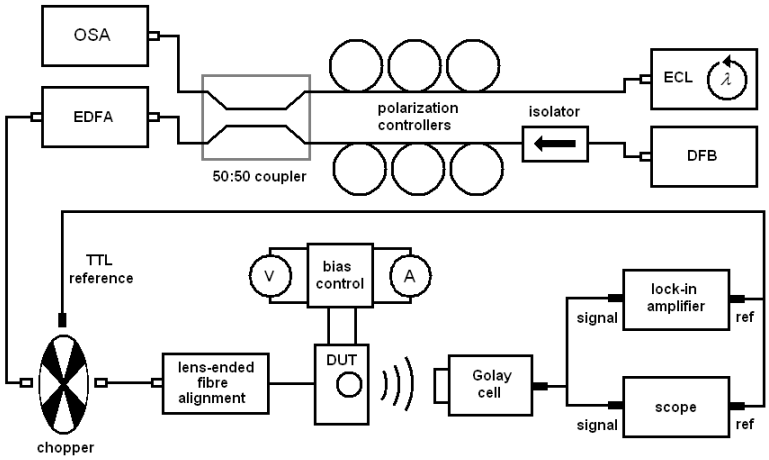


In a square law detector, response is proportional to the intensity:

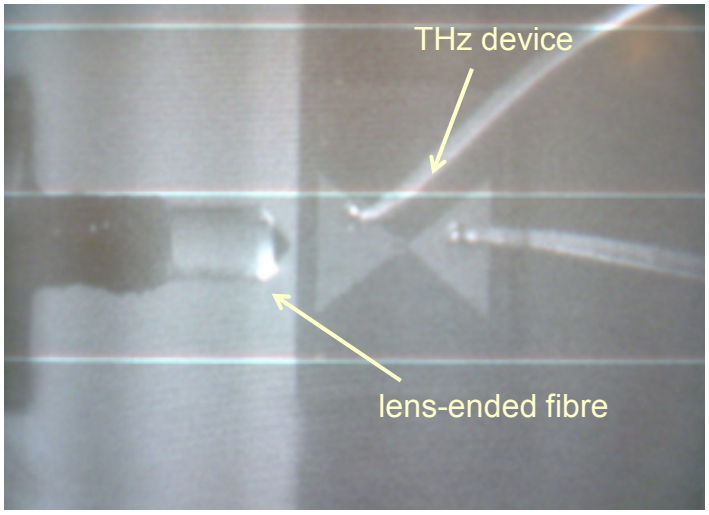
$$|E|^2 = \left(E_1^2 + E_2^2\right)\left(1 + \frac{2E_1E_2}{E_1^2 + E_2^2}\cos(\delta\omega t - \phi)\right).$$

Seek beat frequency in THz

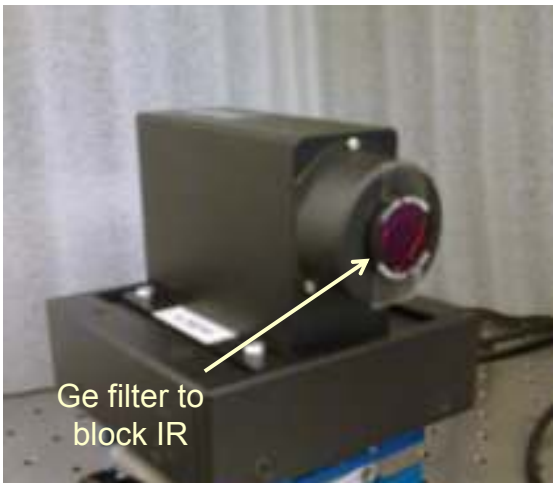
Example experimental setup (2)



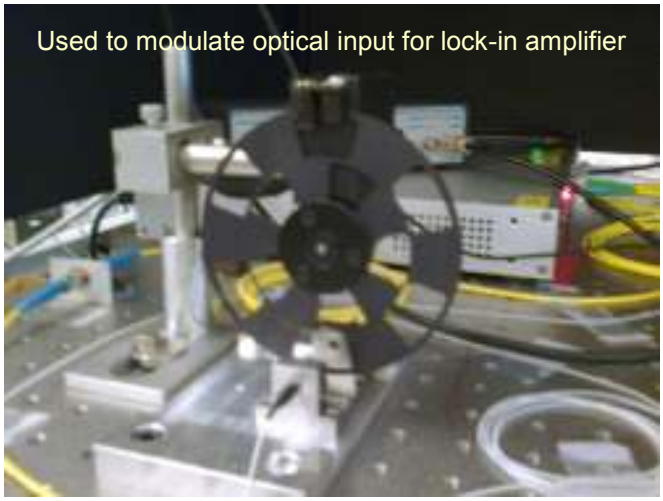
Lens-ended fibre and THz device



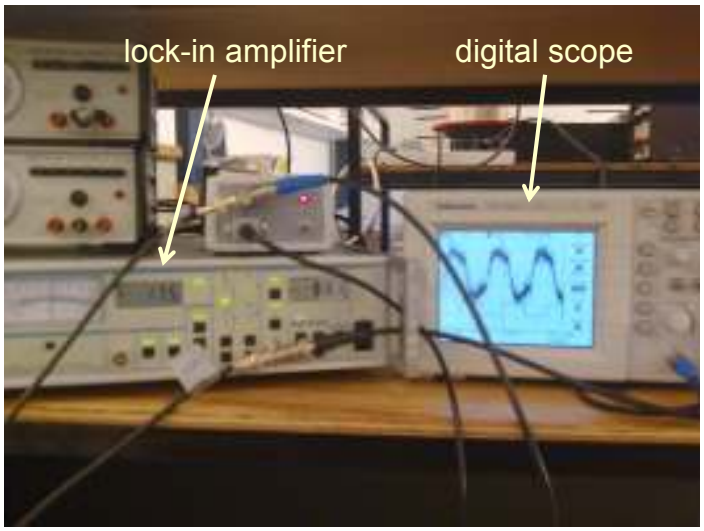
Golay cell



Chopper



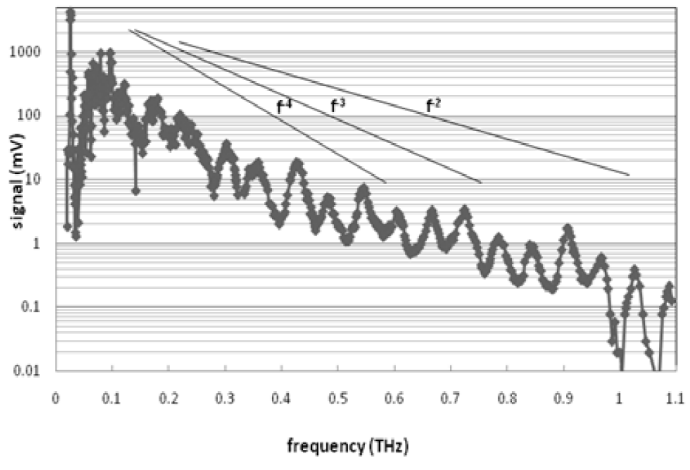
Lock-in amplifier (and scope)



Lock-in amplifier basics

- Allows detection of weak signals buried in noise
  - Input signal multiplied by a reference signal modulated at the same frequency
  - Leads to DC component proportional to input signal amplitude
  - Can be optimised by adjusting the phase
  - Other frequencies filtered out using band-pass filters

THz power

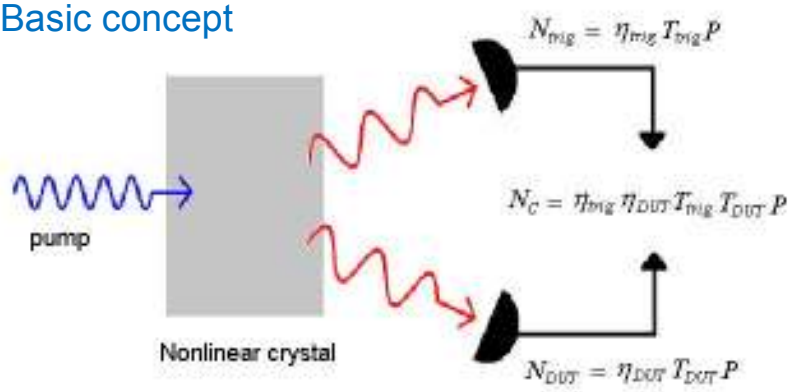


Example experimental setup (3)

- Set up to measure detector quantum efficiency using correlated photons
- Elements of set up controlled centrally using LabView

Example experimental setup (3)

Basic concept



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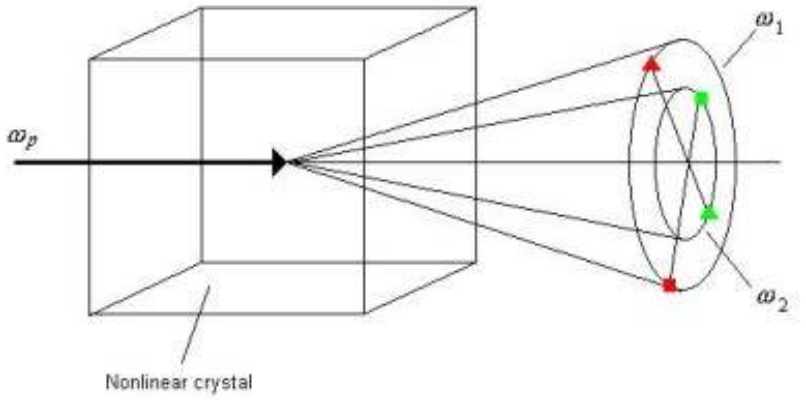
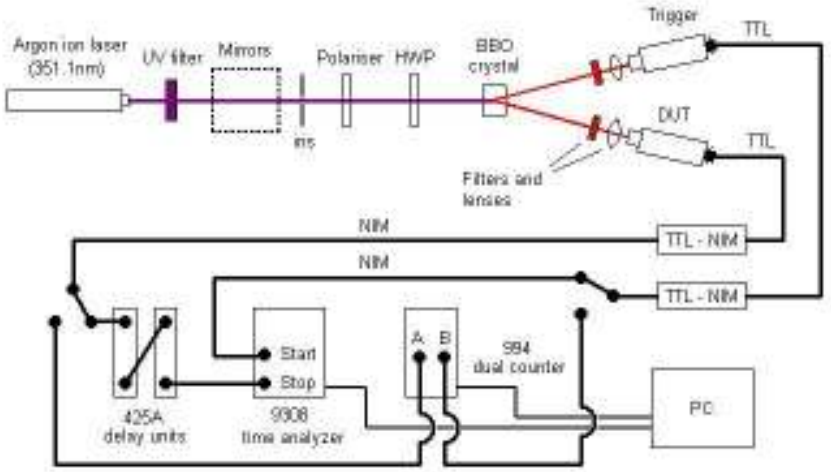
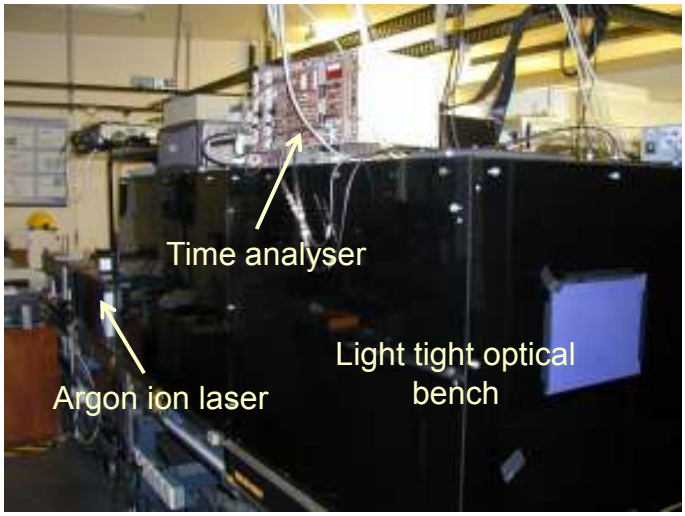
Nonlinear crystal – parametric down conversion



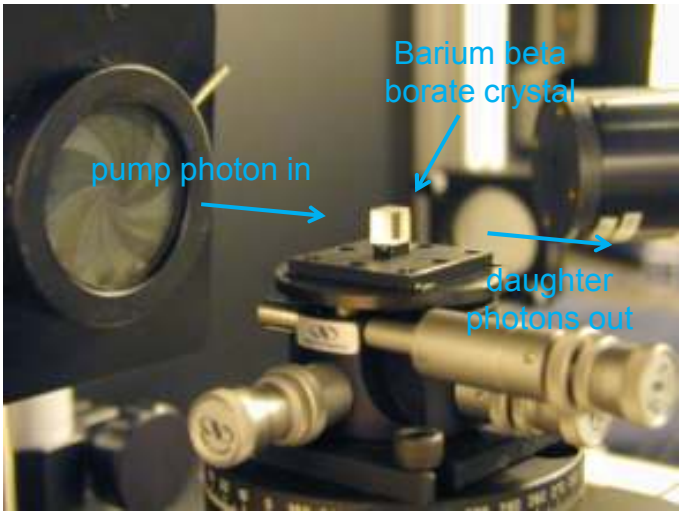
Example experimental setup (3)



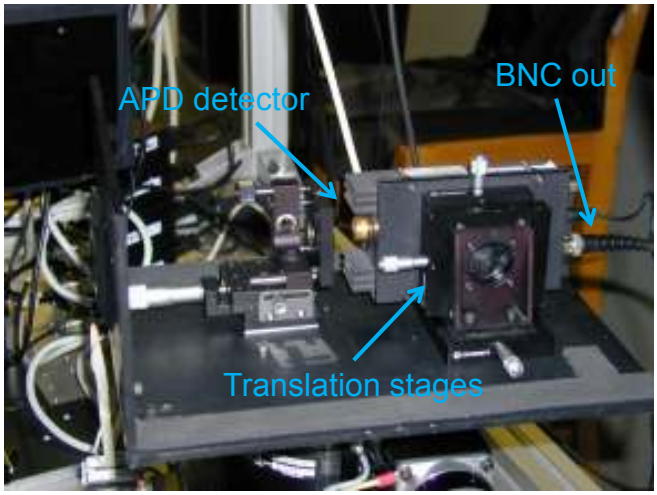
Light-tight environment



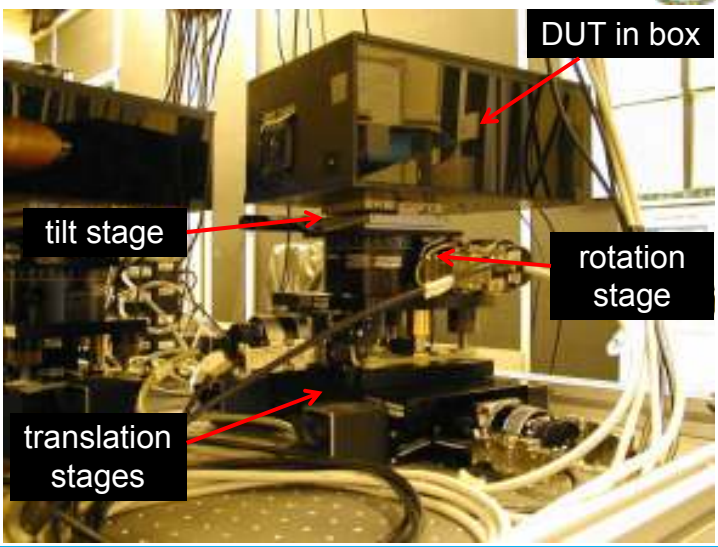
Nonlinear crystal



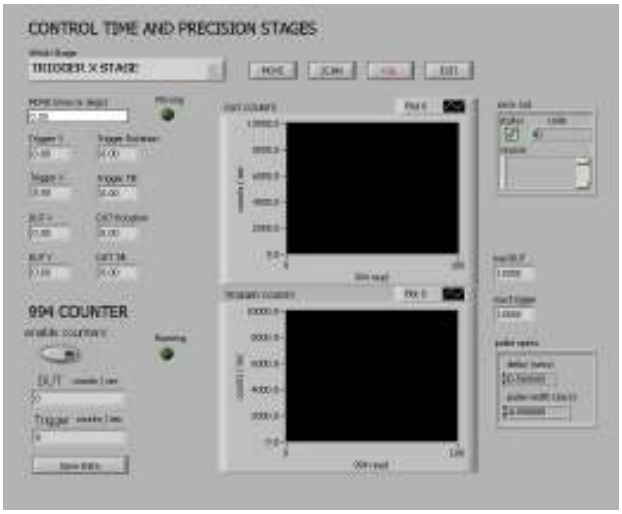
Trigger photodetector (APD)



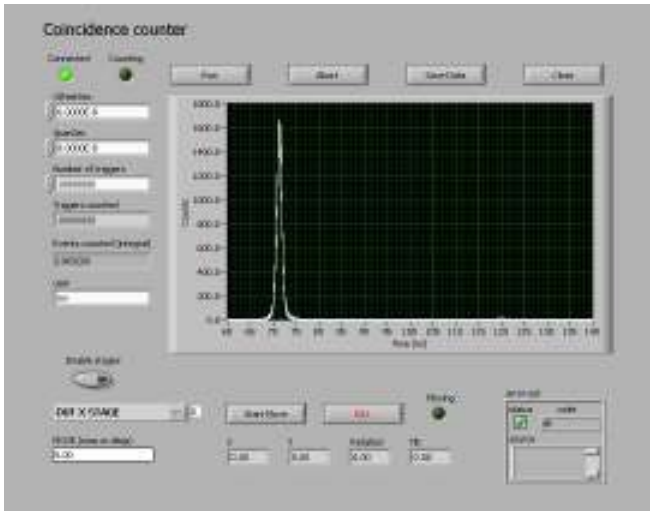
Device under test (DUT) in box



LabView – aligning and scanning



LabView – coincidence counts



References to examples

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Mutual optical injection in coupled DBR laser pairs
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