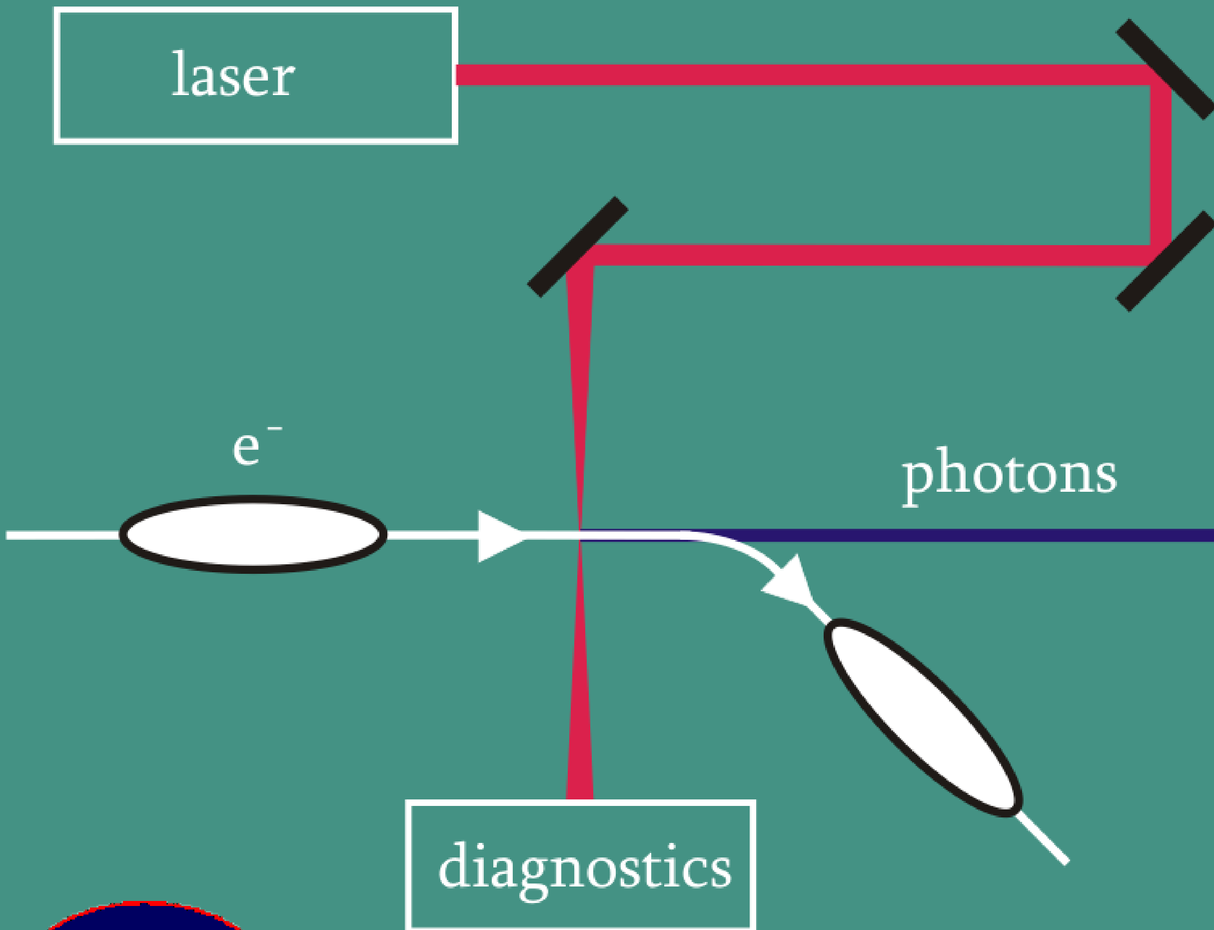
Fibre lasers for accelerators

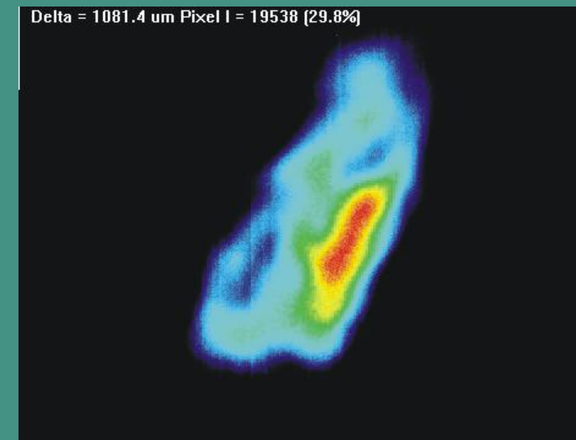
L. Corner, L.J. Nevay, R. Walczak

John Adams Institute for Accelerator Science
Oxford University

International Workshop on Linear Colliders
Wednesday 20th October 2010

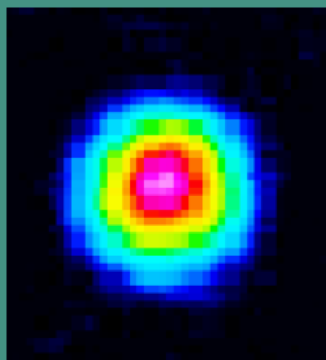
Laserwire experiment





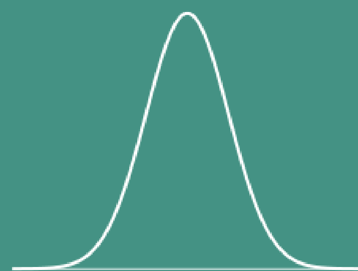
Laser-wire requirements

< 1 μm spot size



Excellent Gaussian spatial mode quality

$M^2 < 1.1$



$\Delta\lambda = 2$ nm

Narrow spectral width (< 2 nm)

- Repetition rate locked to accelerator.
- Low beam jitter - pointing stability.
- Linear polarisation.
- Specs - 100 μJ (ir), 50 μJ (green) 1 - 10 ps.

High energy (> 100 μJ) @ high rep. rate (6.49 MHz)

Fibre laser

Photonic crystal fibre - large core, single mode

Why fibre lasers?

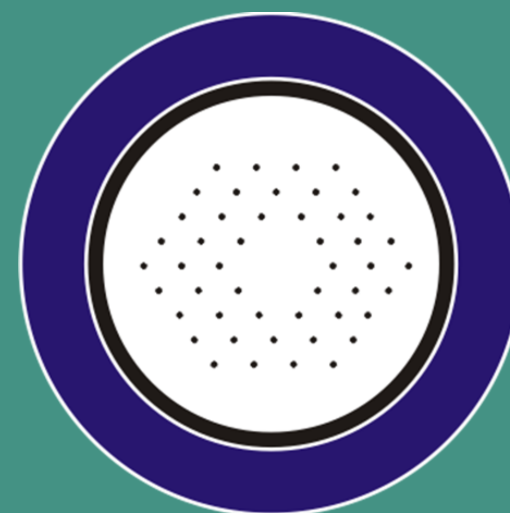
Fibre is optical waveguide - single mode fibre gives near perfect spatial mode.

High surface area/volume ratio means no active cooling is needed.

Lasing ions (Yb, Er) can be doped into waveguide core to make laser oscillator or amplifier.

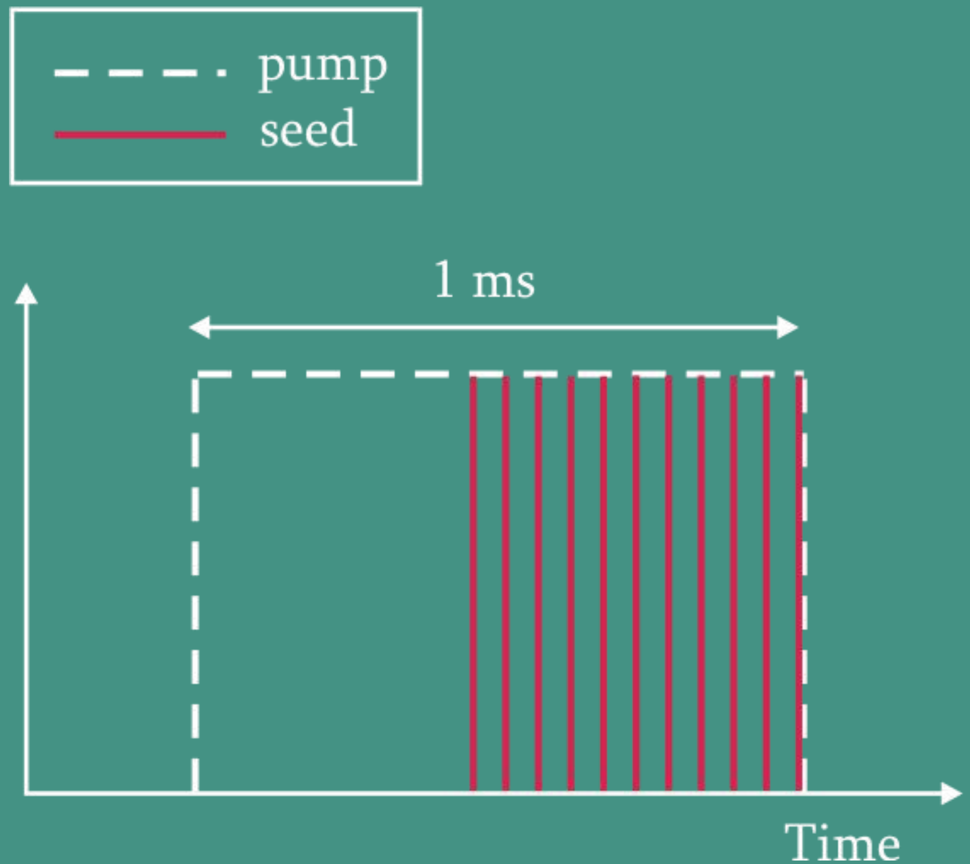
Photonic crystal fibre (PCF) has large core area (high energy) and is single mode (good spatial quality).

Plan - take output of commercial fibre laser (~ 1 μJ @ 6.49 MHz) and amplify in rod type PCF to 100 μJ.



photonic
crystal fibre

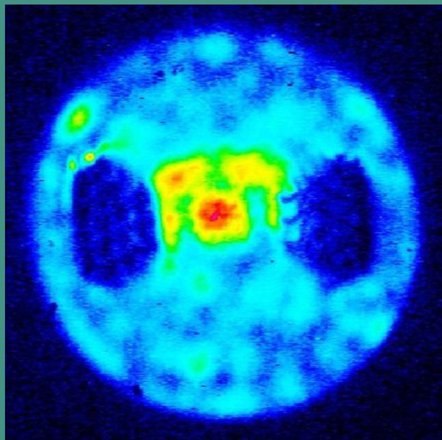
Burst mode amplification



unamplified seed pulse train

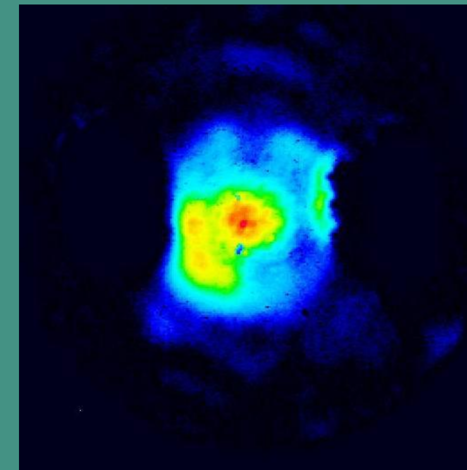
input pulse energy 0.7 μJ

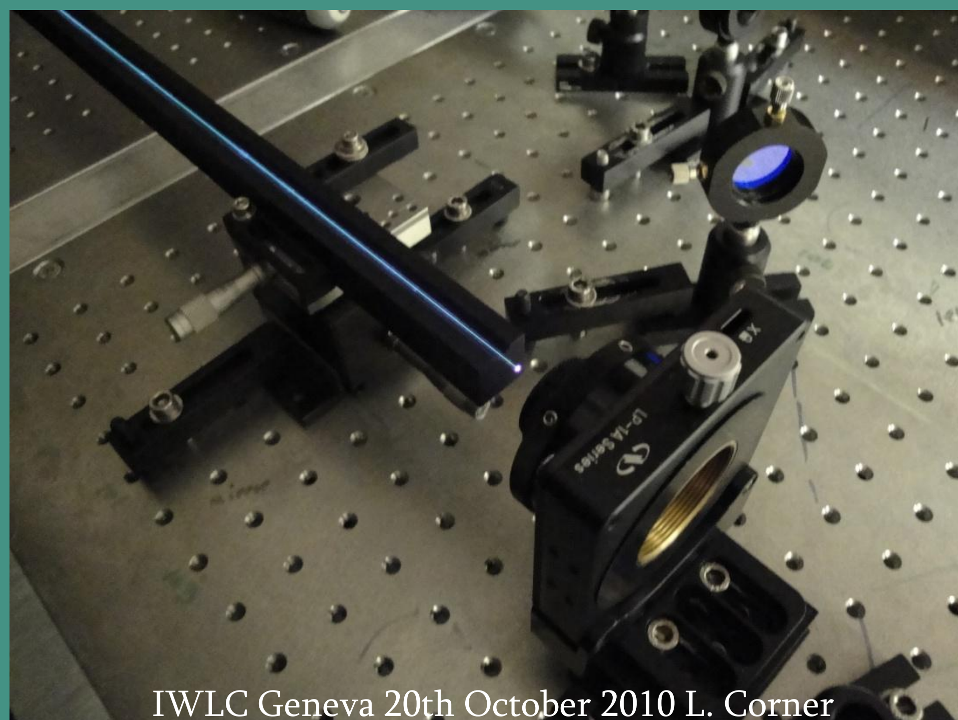
Results



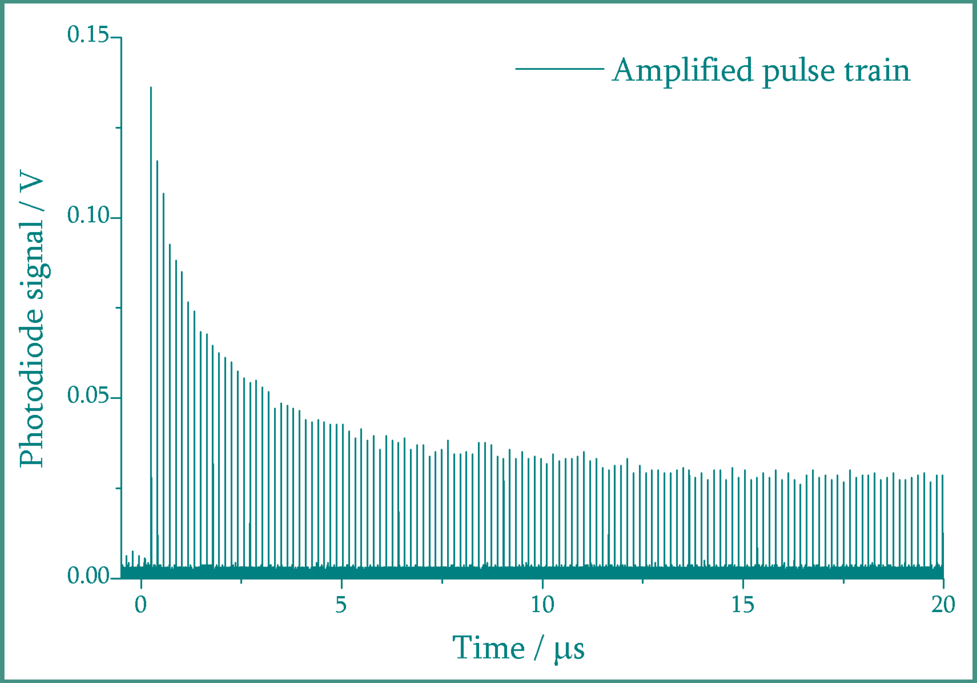
Improvement of coupling of light into PCF core

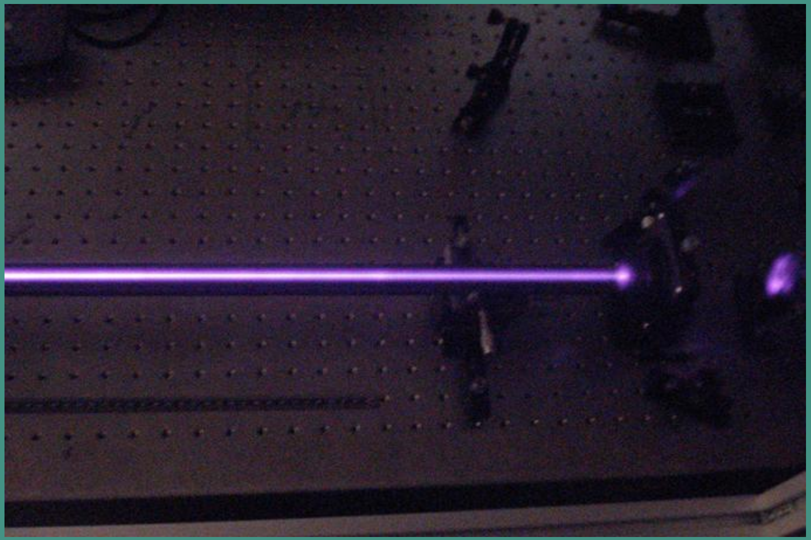
Successful burst mode amplification in 70cm PCF





Amplification results

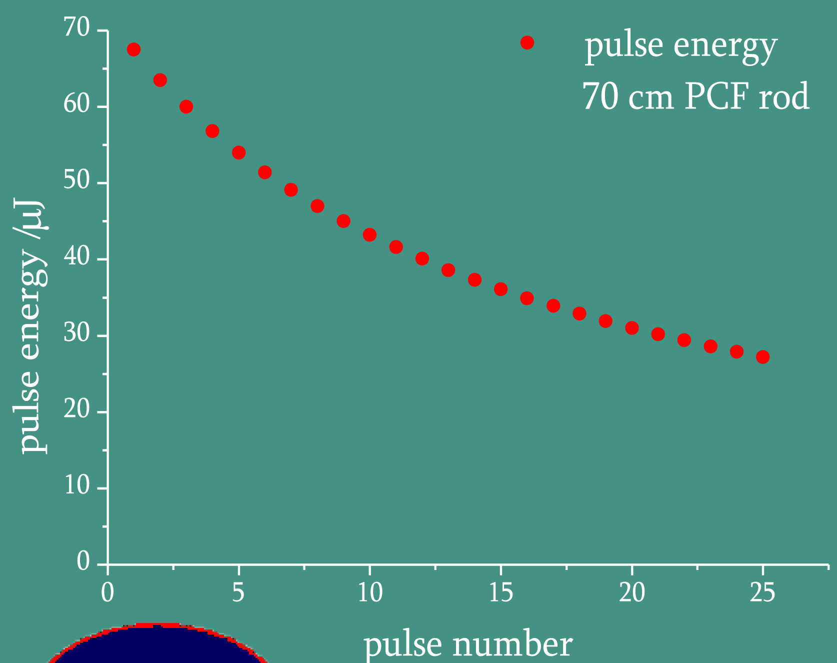


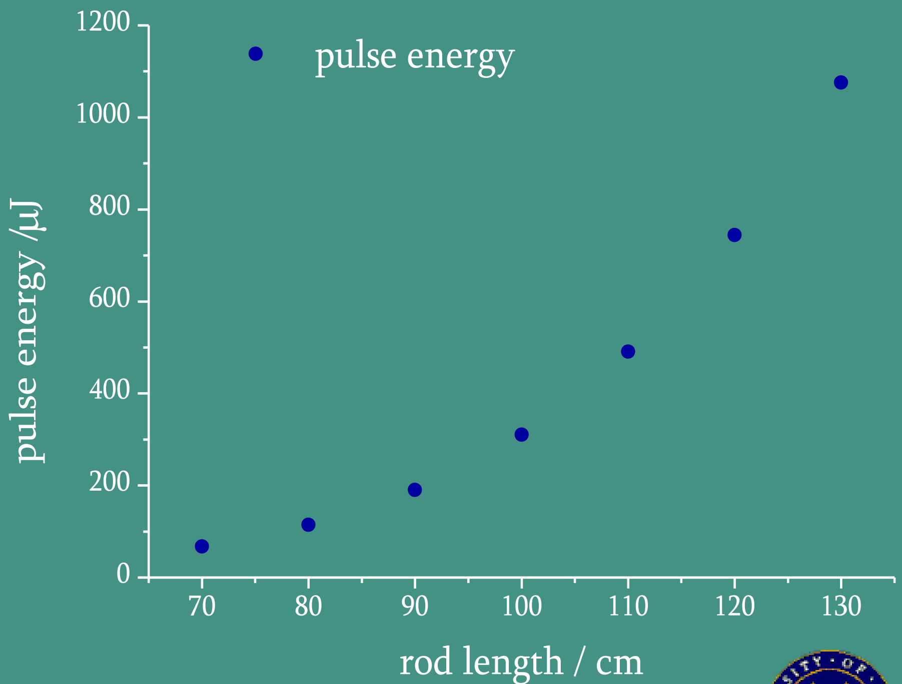


- Initial results - first pulse in train ~ **95 - 105** µJ.
- Have achieved design spec. for pulse energy.
- Currently 2 Hz (limited by diagnostics).
- Can go to ATF2 6 Hz.
- This result is in 70 cm length of fibre.

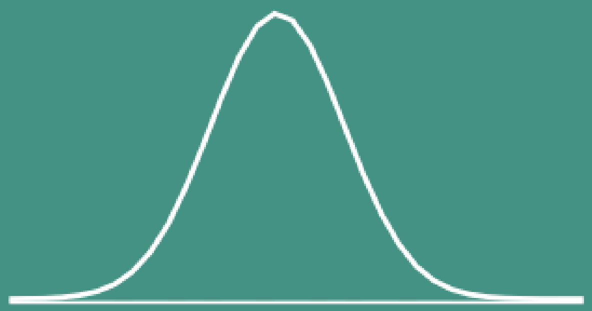
Increasing pulse energy

- Current amplification in 70 cm photonic crystal fibre rod.
- Output ~ 100 μJ - would like higher energy.
- Initial theoretical modelling confirms shape of amplified pulse train.
- Predicts pulses energies of up to 1 mJ if we use 60 cm fibre after first 70 cm rod.

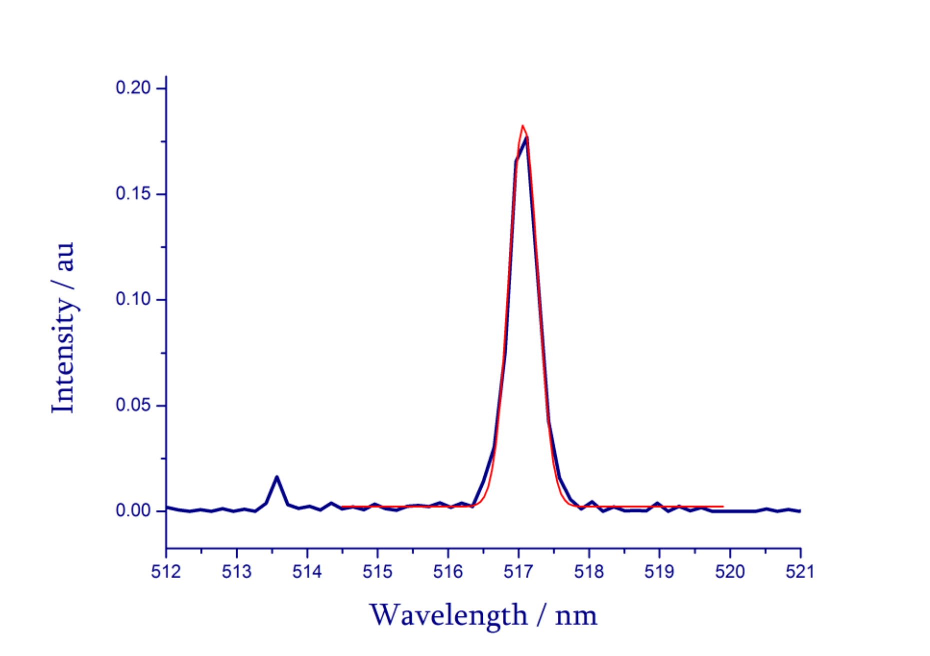




Spectral width?



$\Delta\lambda < 2$ nm



- Pulse duration compressed from 220 ps to 2.5 ps (unamplified).

FWHM = 0.5 nm

- Meets specification

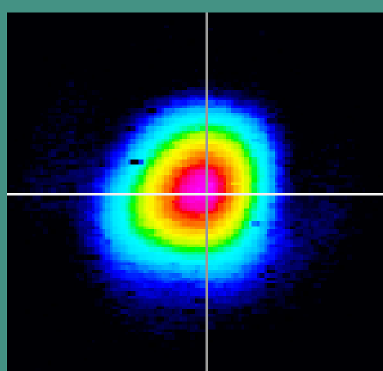
Spatial quality?

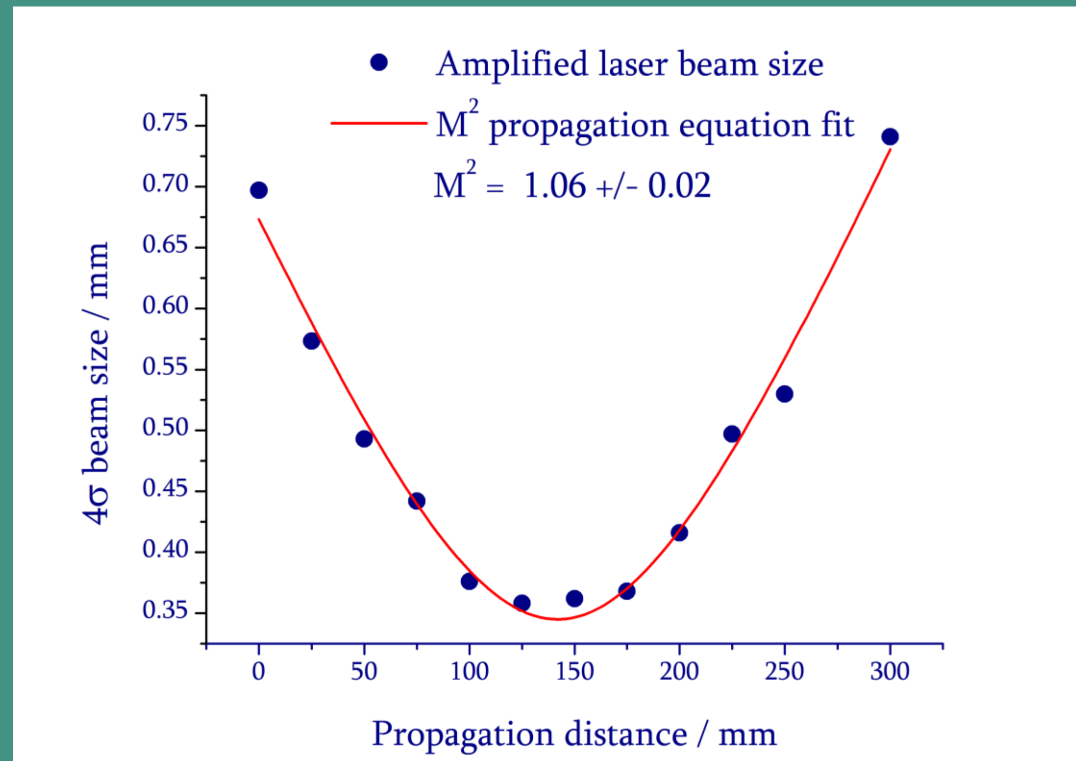
$M^2 < 1.1$

M^2 measured from fit of laser beam size through a focus

Results: $M^2_x = 1.06 \pm 0.02$

$M^2_y = 1.00 \pm 0.03$





- Meets specification

Future plans for fibre laser research

Finish fibre laser and deliver to ATF2:

- better beam quality (smaller spot size) - higher resolution.
- less pointing jitter.
- better reliability (current laser problematic).
- test of fibre laser in accelerator environment.
- faster scanning due to higher repetition rate.

But also to develop fibre laser systems for other applications in accelerators - diagnostics, sources, wakefield accelerators etc.

Fibres have many advantages over other laser sources that make them ideal for accelerator environments - lower power drain (efficient), low heat load (small quantum defeat, high area/volume ratio), single oscillator, safe distribution to many amplifier architecture (reduced cost compared to many separate lasers?).

In particular can have versatile manipulation of pulses much more easily and safely than in free space.

All fibre pulse train generating network