Development and calibration of a scintillator-based ion beam profiler

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STFC

LIBRA (**L**aser **I**nduced **B**eams of **R**adiation and their **A**pplications)

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Talk outline

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- Development of in-situ diagnostics
- 'Footprint' monitor & first light
- Scintillator calibration
- Revising the design
- Fibre optic bundle testing
- Conclusions and future work

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In situ ion diagnostics

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- Higher rates of data acquisition expected

  1 per hour (pre 2006)- 20 seconds (2009) – 10 Hz(?)

- Radiochromic Film (RCF) and etched plastic (CR39) used-1+ hour processing timescale
- Passive imaging media are increasingly unsuitable

  Expensive, effort intensive, slow

- New designs required for ion & gamma diagnostics

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Active ion detectors

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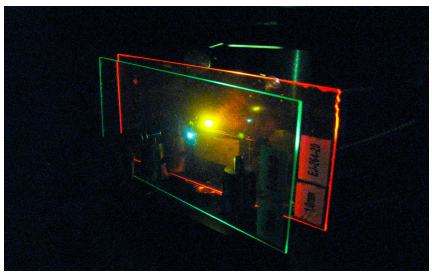
-Polyvinlytoluene scintillator signal recorded on a CCD camera



- Need high dynamic range – ion flux will vary depending on ion energy.
- Repetition rate – must be able to acquire data at the laser repetition rate (Gemini – 1 shot every 20 seconds)
- Large number of pixels (>1 Mpixel)

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Ion beam energy sampling

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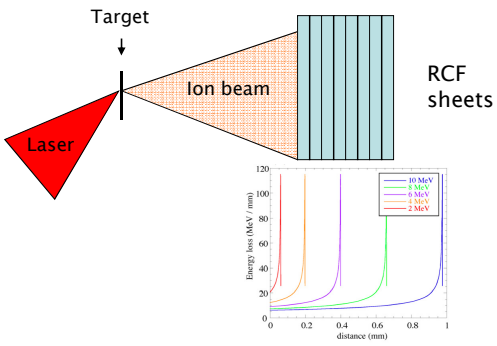

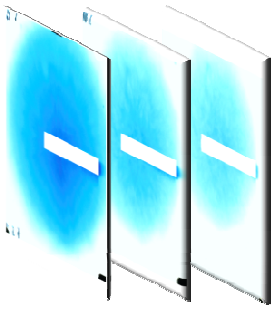

- 'Sandwich' of Radiochromic Film (RCF) placed behind target rear surface
- Stopping range of ions in the 'stack' used to recover spatial profiles of the beam at known energy intervals
- High spatial and energy resolution, good dynamic range, characterised
- Takes time to prepare and scan

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Proton beam profiler

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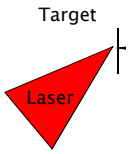

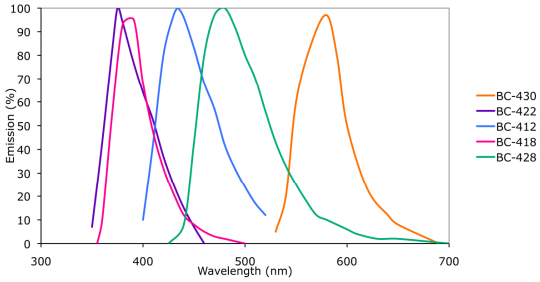

- Multiple scintillators giving ion energy bins with flexible configuration
- Scintillator thickness determines energy observation window
- Each scintillator has a separate central emission wavelength
- Gated CCD isolates ion signal from other ionising radiation

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'Footprint' monitor

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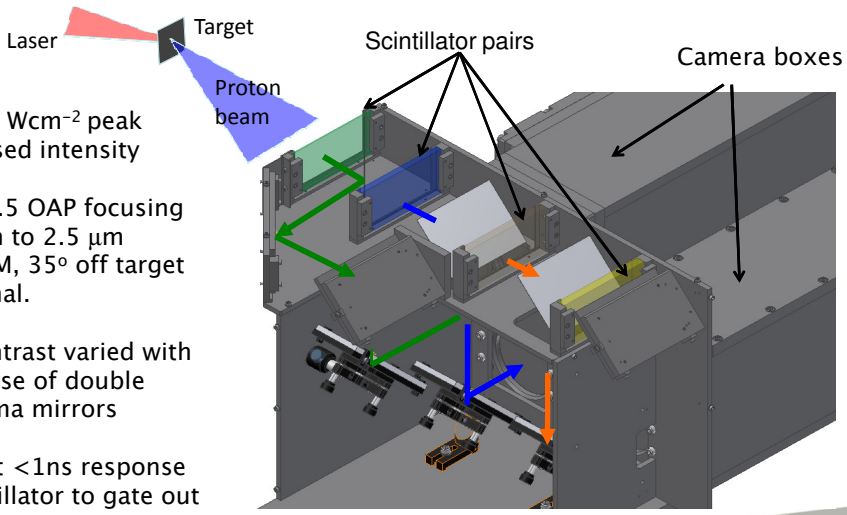

- 10^{21} Wcm^{-2} peak focused intensity
- F/2.5 OAP focusing down to 2.5 μm FHWM, 35° off target normal.
- Contrast varied with the use of double plasma mirrors
- Fast <1ns response scintillator to gate out electron / x-ray signal

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Initial footprint results

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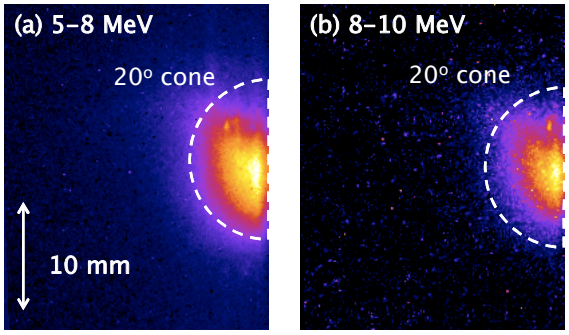

- Proton footprint for a 100nm Al target shot at high contrast (> 10^9) at an intensity of ~ $5x10^{20}$ Wcm^{-2}
- Absolute calibration will allow the diagnostic to act as a proton beam calorimeter

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Multi shot results

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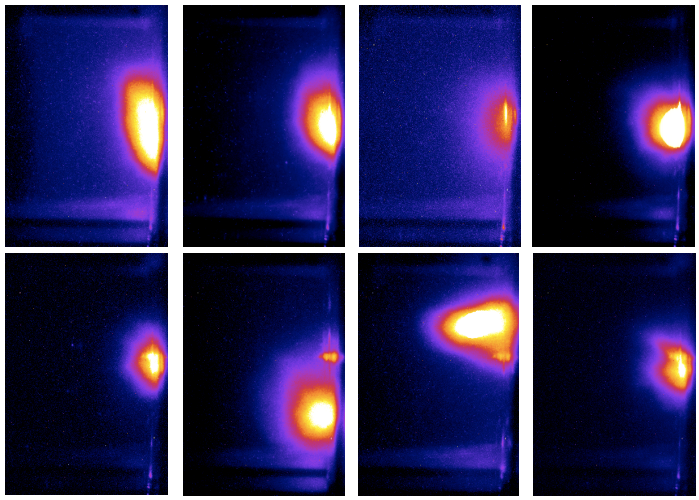

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High & Low laser contrast

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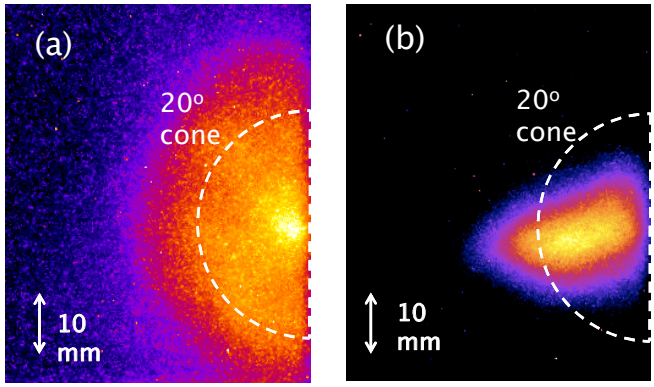

- Proton footprints in the energy range of 5–8 MeV for 6μm Al
- (a) Low contrast (~10^7) and (b) high contrast (> 10^9) beam, focused to an intensity of ~ 5×10^{20} Wcm^{-2}
- 20° half-cone is shown for reference

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Beam Divergence control

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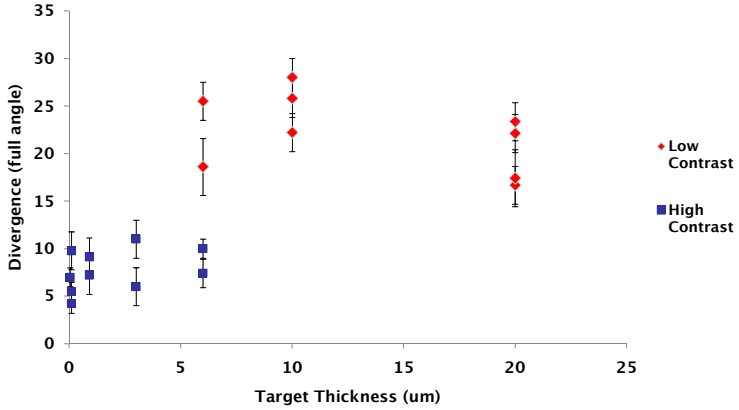

- Al foils shot at best focus with 50 fs pulses
- Divergence independent of target thickness
- Divergence controlled by laser contrast

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Scintillator Calibration

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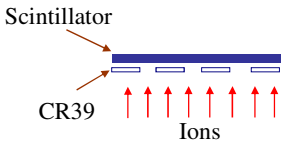

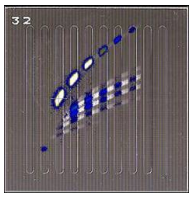

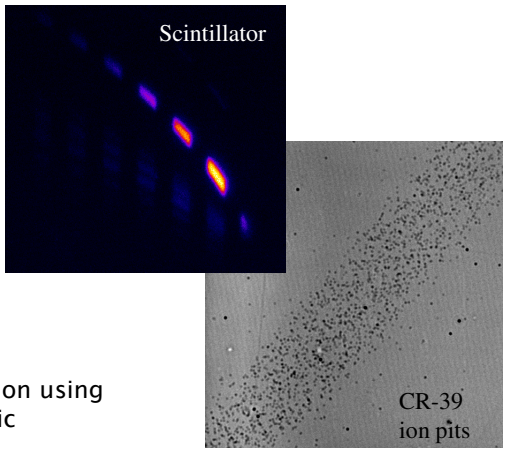

- Absolute in-situ cross calibration using slotted CR-39 in front of plastic scintillator.
- No. of ion hits recorded on CR-39 strips is referenced against scintillator CCD counts.

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Scintillator Calibration

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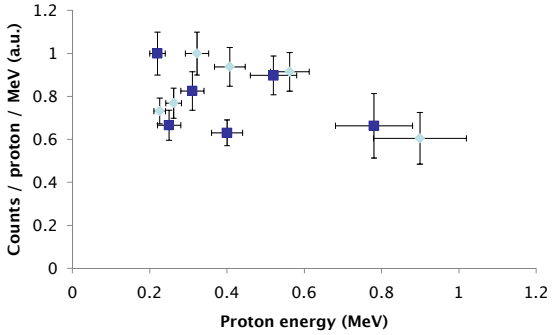

- Cross-calibration performed on Astra TA2
- Cross-calibration results only upto 1 MeV

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Scintillator calibration

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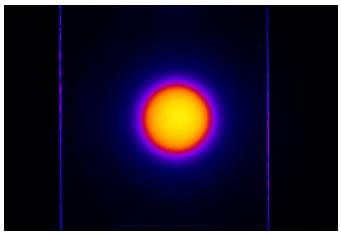

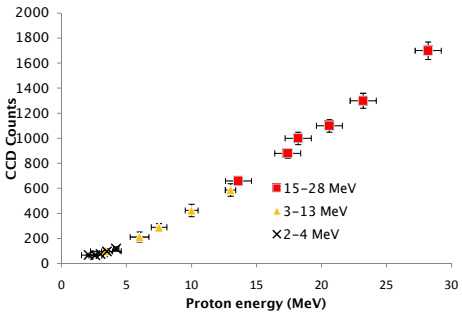

- University of Birmingham Cyclotron and Surrey Ion Beam Centre
  - Light output as a function of energy and beam current
  - Initial analysis suggests that response is near linear for higher energies

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Scintillator calibration

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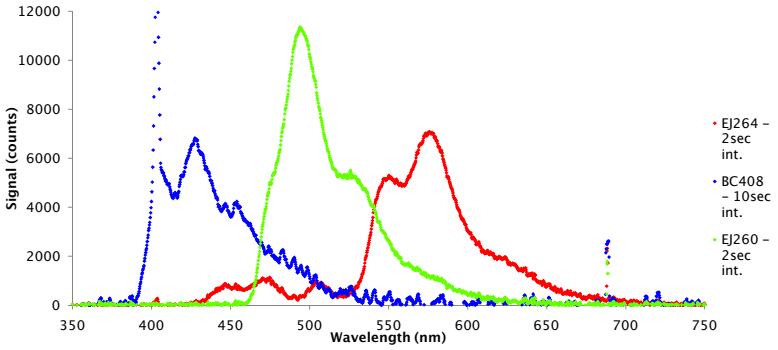

- Scintillator ouput analysis
  - How do the output spectra compare to manufacturers' claims?
  - Angular dependence of light output
  - Caution needed when pairing scintillators

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Beam sampling "head"

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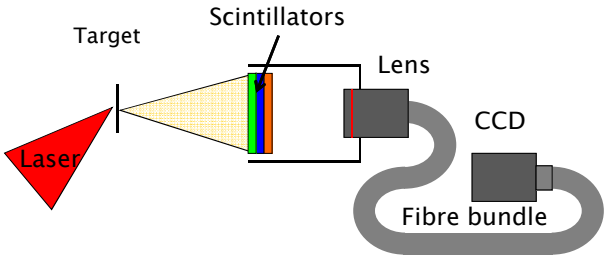

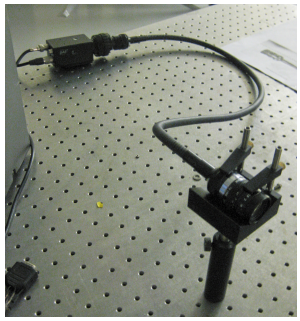

- More compact, flexible system. Designed for easy deployment into any experimental set-up.
- Lens and optical fibre bundle relays beam profile image outside of vacuum chamber to CCD cameras.
- Reduces diagnostic footprint inside chamber, increases diagnostic resolution and light collection.

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Fibre bundles

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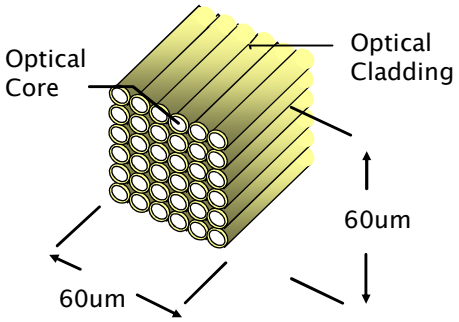
- High resolution 800 x 800 fibre bundles
- Fibre bundles can relay signals from scintillators or MCPs to CCDs.
- Immune to EMP so can be situated where cameras can't.
- Broad range of transmission wavelengths



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Fibre bundle testing

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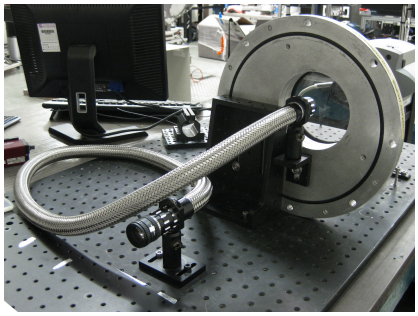
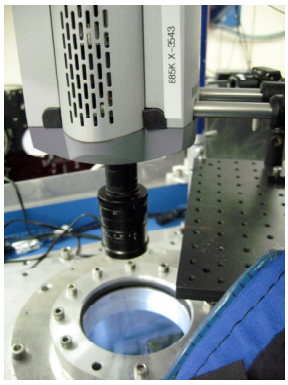


Characterisation of a 800 x 800 fibre bundle



Intensified EM-CCD camera images fibre bundle head inside interaction chamber.

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Fibre bundle results

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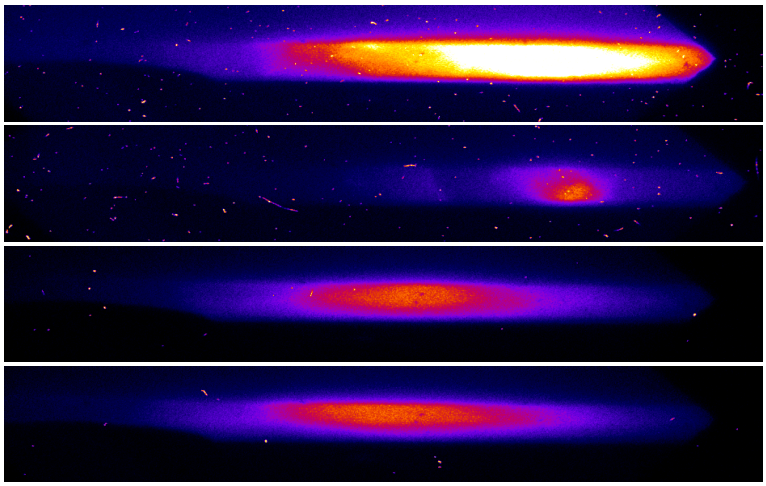

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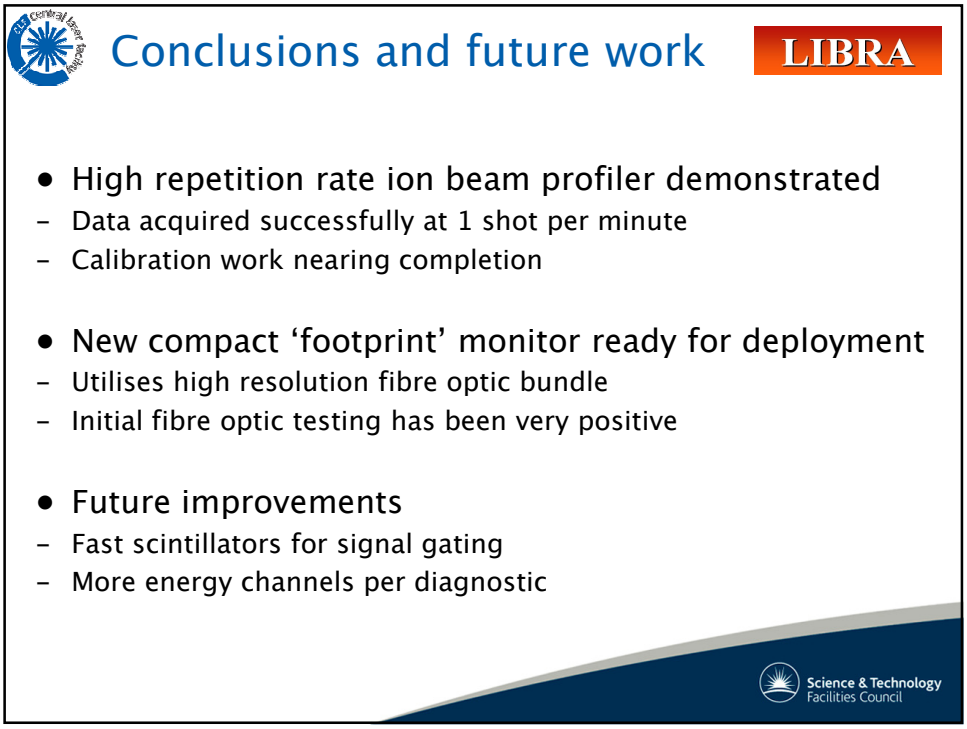
Conclusions and future work
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• High repetition rate ion beam profiler demonstrated
– Data acquired successfully at 1 shot per minute
– Calibration work nearing completion
• New compact 'footprint' monitor ready for deployment
– Utilises high resolution fibre optic bundle
– Initial fibre optic testing has been very positive
• Future improvements
– Fast scintillators for signal gating
– More energy channels per diagnostic
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