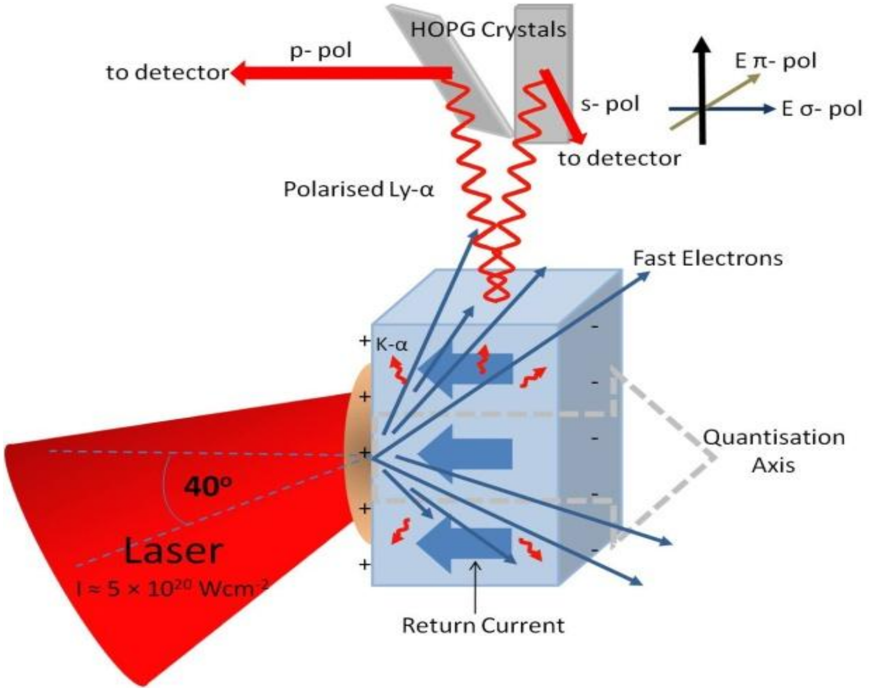
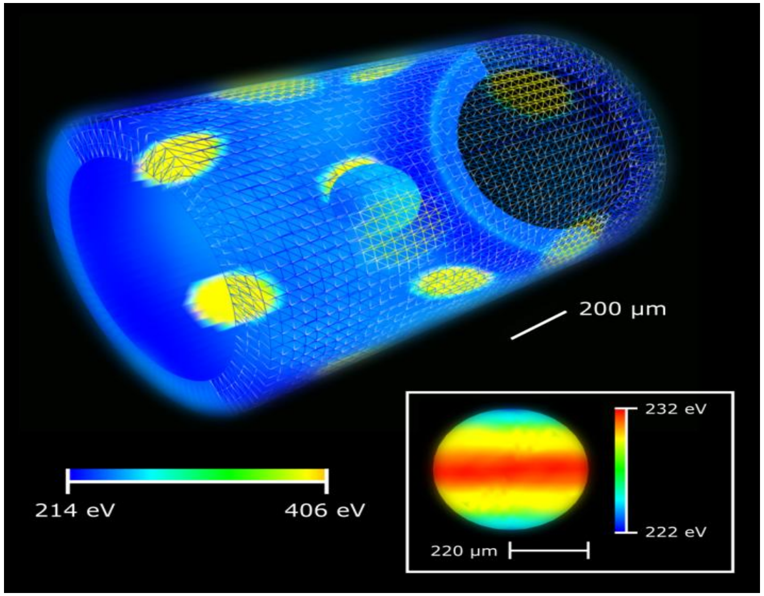
ICF research at the University of York in 2010/11

John Pasley





Presented at the CIFS workshop, AWE, 15/3/2011

Plasma physics at York

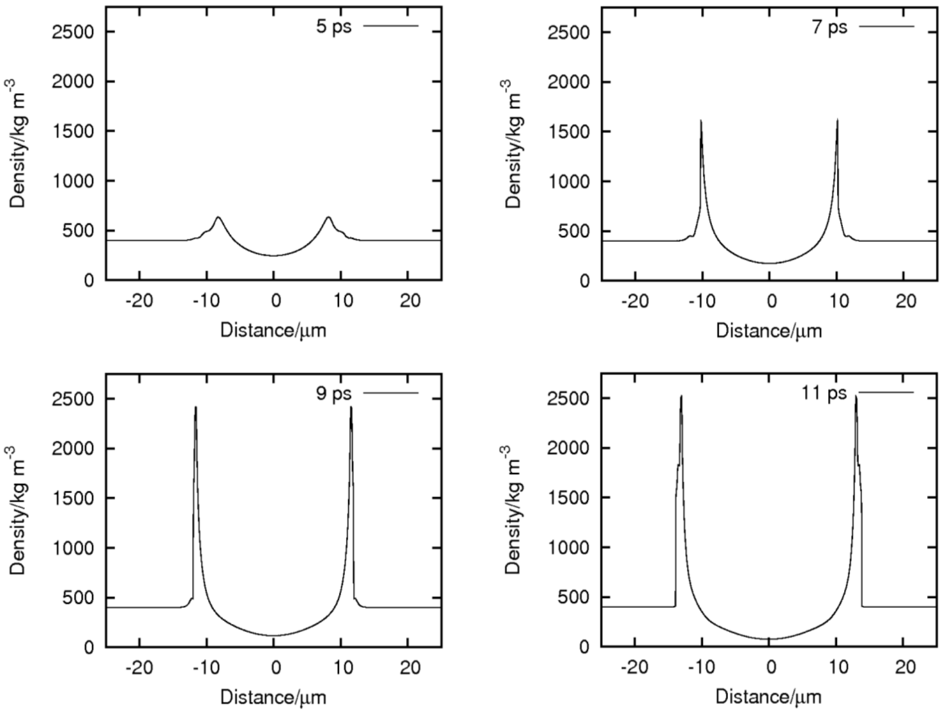
FDTN FUSION DOCTORAL TRAINING NETWORK

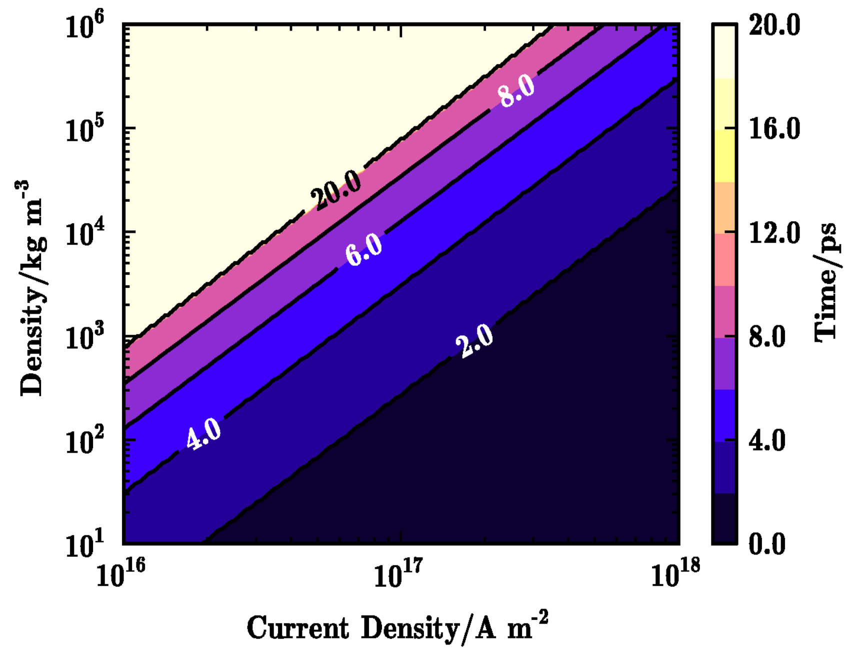
- Currently 7 academic staff – soon to be 10, with 3 new technological plasma appointments
- Cover IFE and MFE
- New building under construction for ‘York Plasma Institute’
- MSc in plasma physics
- Doctoral training network involving York, Durham, Manchester, Liverpool

ICF related work at York

- Laser to electron coupling + electron transport and heating studies relevant to fast ignition
- Warm and hot dense matter studies
- IFE reactor vessel radiation transport and damage related studies
- Hydrodynamics driven by short pulse lasers, relevant to FI heater beam interaction
- Small local laser laboratory (0.5 J, 170 ps) set-up for diagnostics testing, training and experiments
- Other things

Shock waves driven by intense LPI

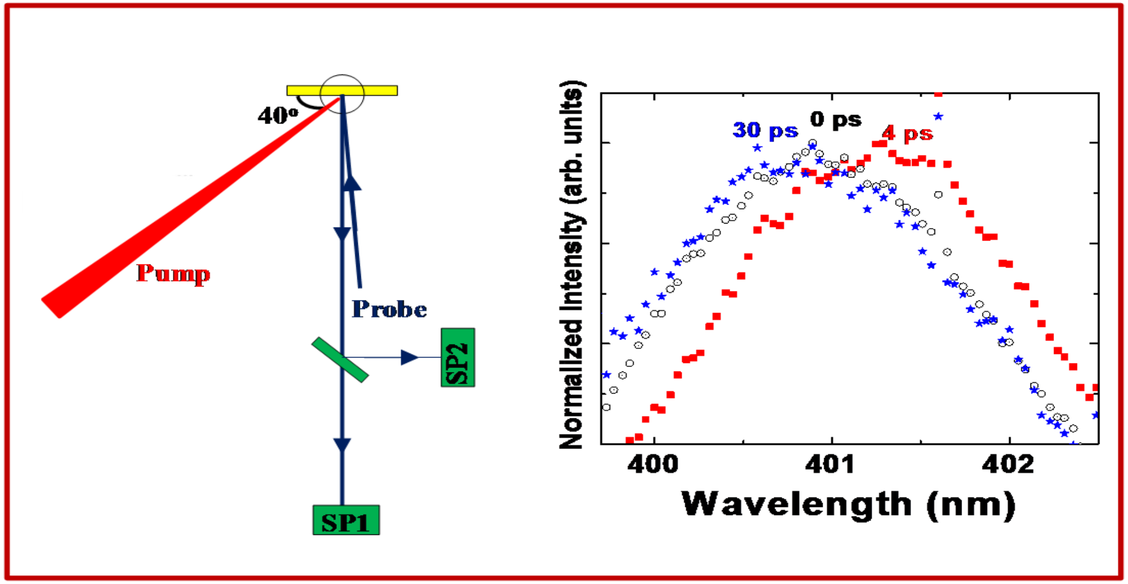




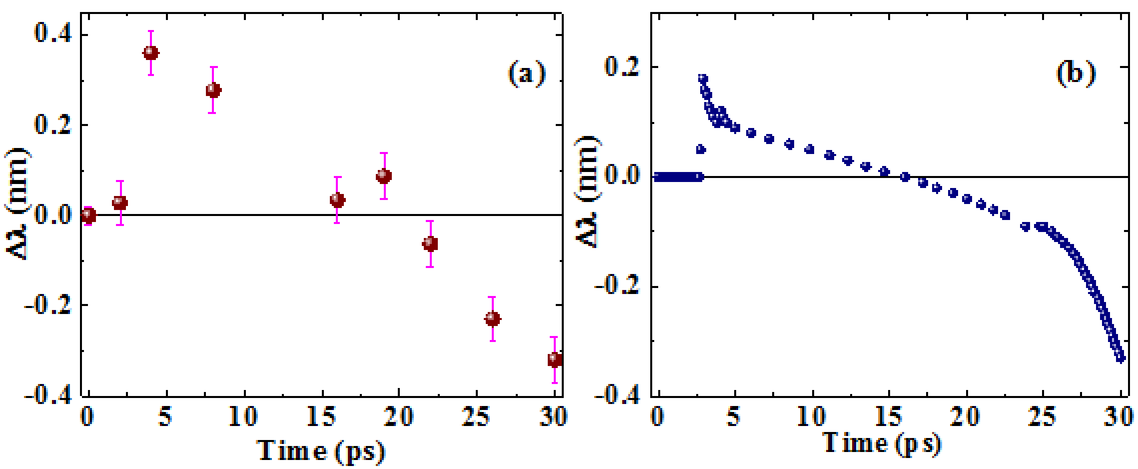
- Analytic and 1-D MHD calculations of the effect of intense beams of hot electrons propagating through matter
- Ohmic heating found to be dominant effect (compared to jxB)
- Shocks can be generated; most easily at lower densities. j_0^2/ρ ratio determines rate at which shocks form

Bush, Robinson, Kingham and Pasley, PPCF, 2010

Shock waves driven by intense LPI



Pump-probe experiment employed, using Doppler shift of 2 ω probe to record hydrodynamics driven by interaction of 1 ω pump beam

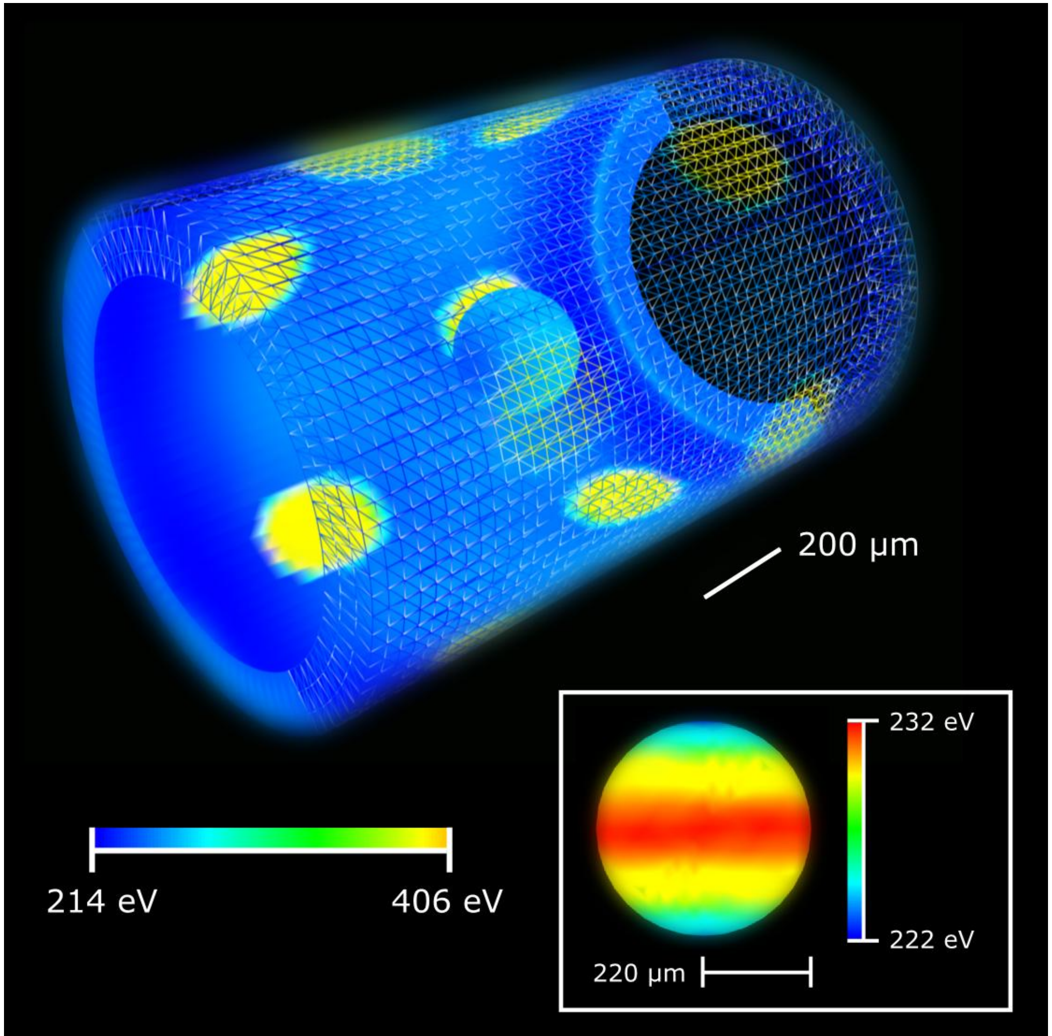


1-D electromagnetic PIC calculation coupled to simple hydrodynamics model shows a reasonable match to the experimental measurements

£120K EPSRC grant recently awarded to further this work

Mondal, Lad, Ahmed, Narayanan, Pasley, Rajeev, Robinson, Ravindra Kumar, PRL, 2010

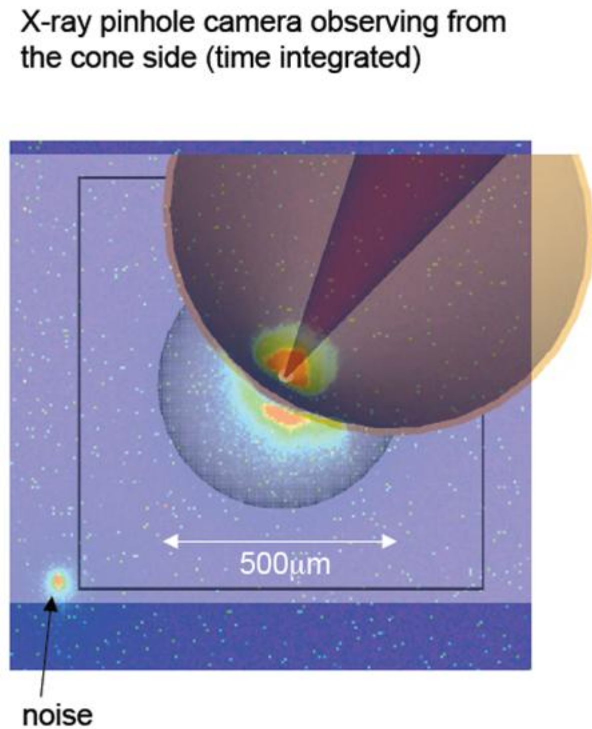
3D view factor modelling

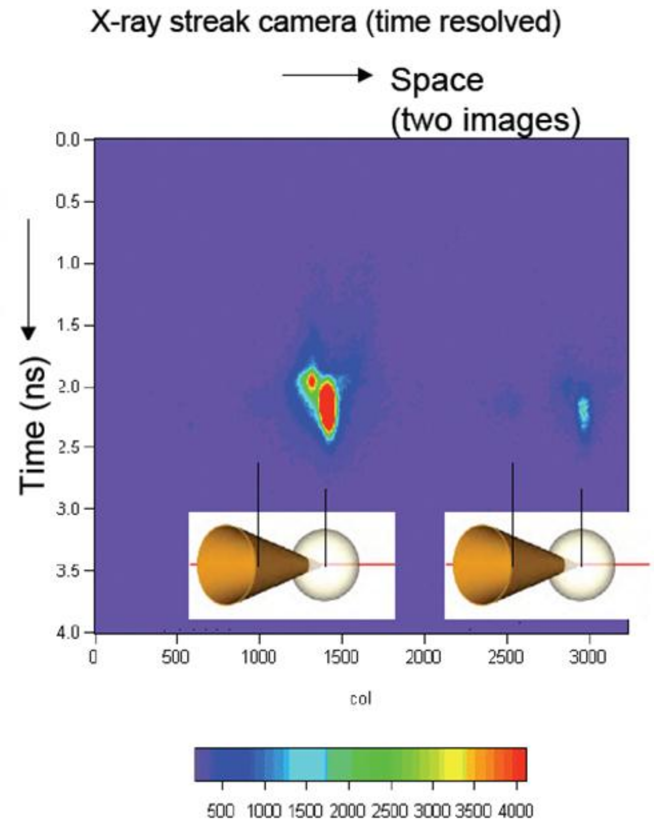


- Mphys final year project conducted by student Matt Fisher
- 3D view factor code with graphical interface for defining geometry and laser beam input
- Gives good match to historical data (e.g. Nova hohlraum illustrated)

Matt Fisher and John Pasley, submitted to Trans. Plasma Sci, 2011

On-going collaboration with Fast Ignition Studies at ILE

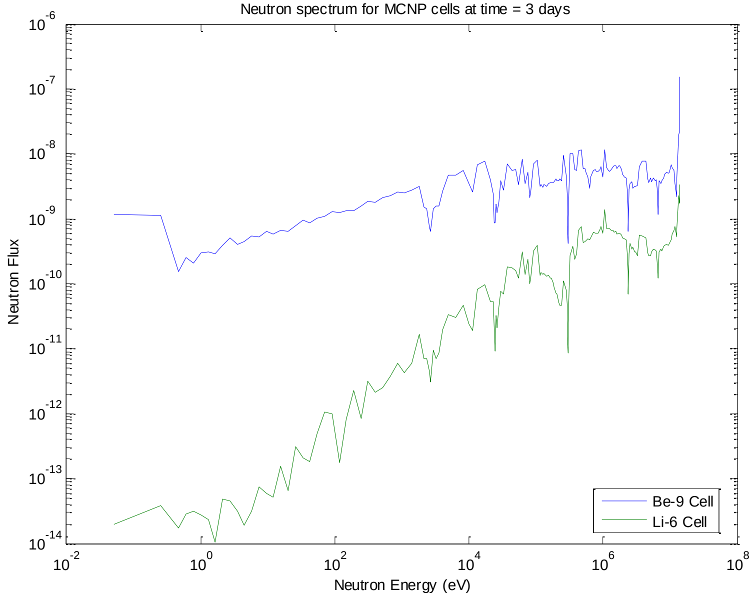


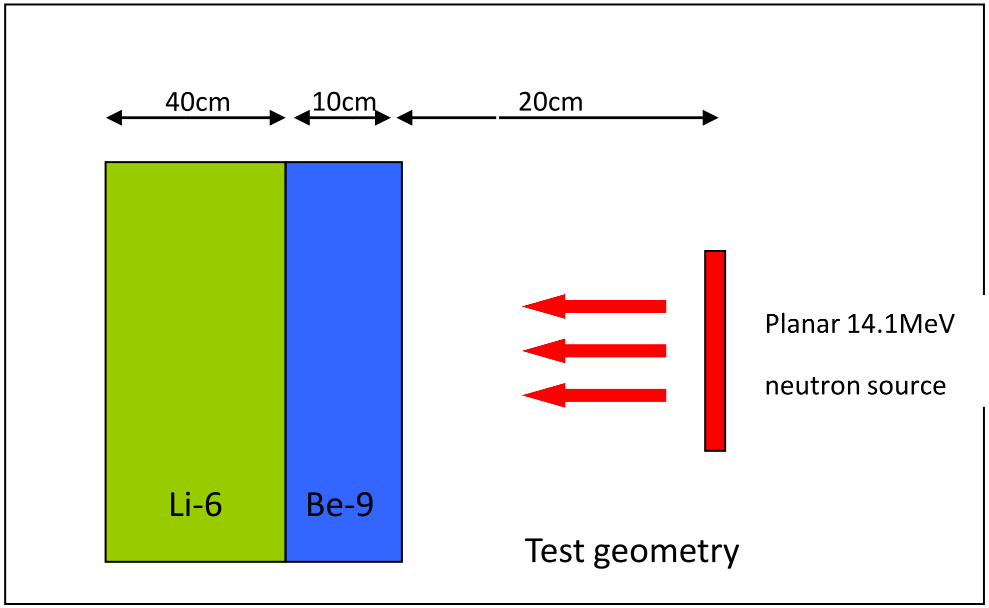


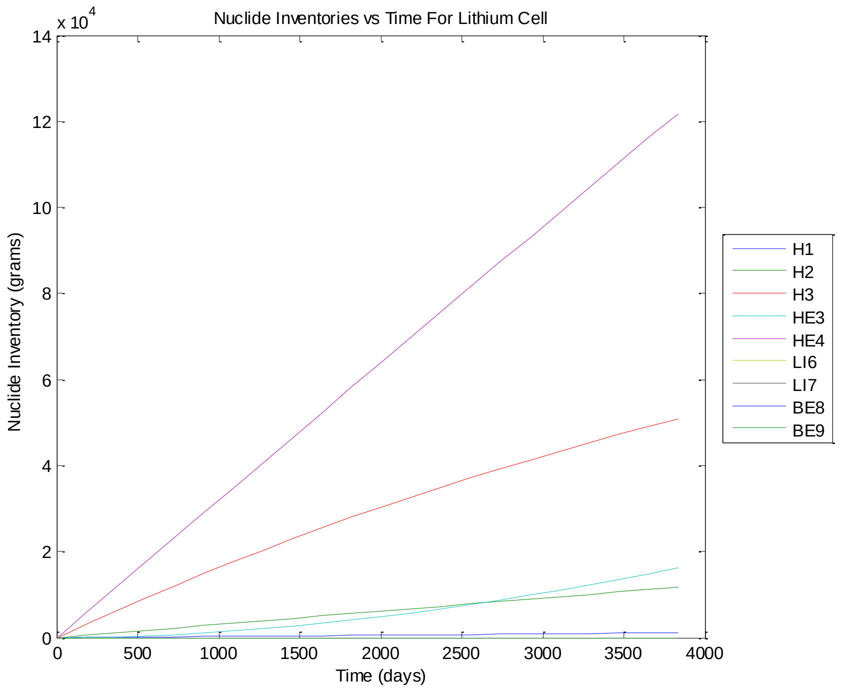
November 2010 experiments appear to show enhanced neutron yield compared to previous those of Sept 2009 experiment and also 2003 experiment; results still under analysis

For results of 2009 experiment see: M. Koga et al, Nucl. Instrum. Meth 2011

MCNP-FISPACT linking code developed (MCNPACT)

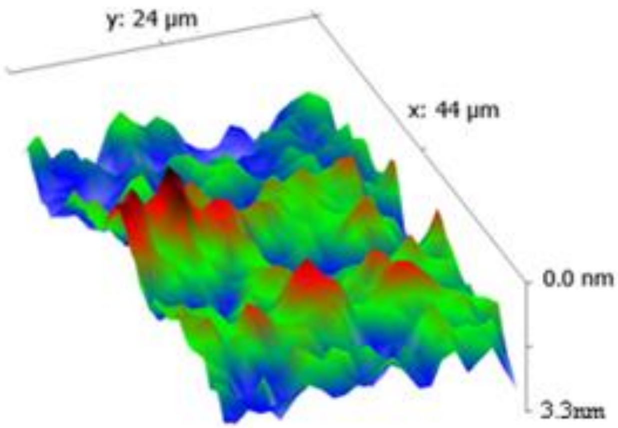




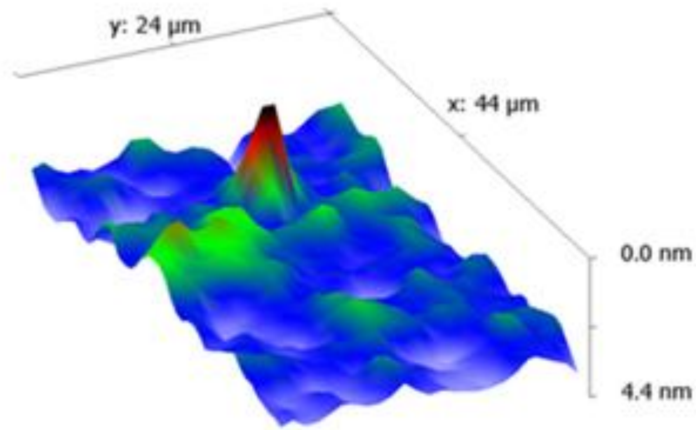


Application to reactor-like problems will be the next step

Preliminary experimental investigations into neutron damage in optical components



Pre-irradiation



Post-irradiation

• Preliminary studies carried out using small doses (at UK National Physical Laboratory 17.6 MeV neutron source) for the purpose of developing experimental techniques

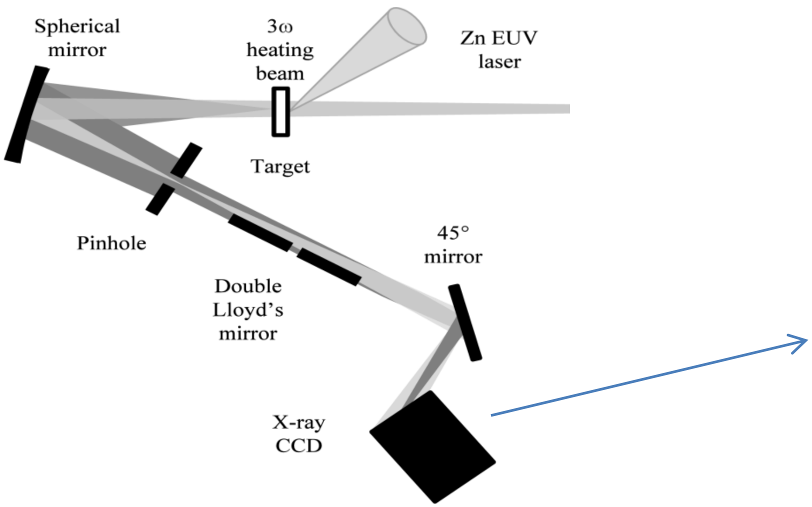
• A range of diagnostic approaches investigated including interferometric investigation of surface damage (above) and spectrophotometry

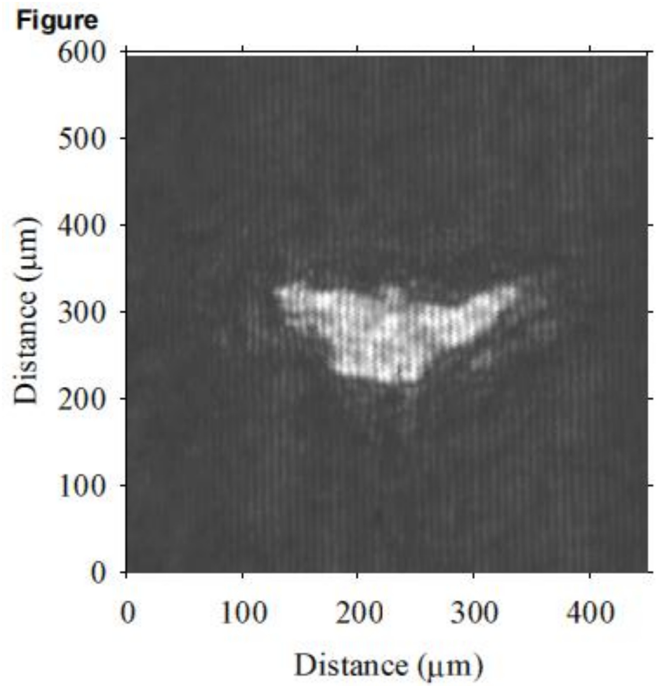
Other Pasley activities

- Continued collaboration with UCSD/ LLNL / Univ Alberta group on electron transport in warm/cold matter experiments

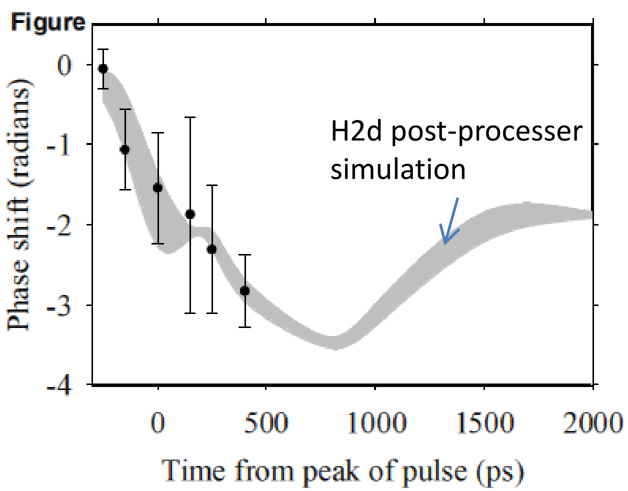
- Shock wave modelling/experiments in collaboration with BARC (India)

Interferometry of warm dense plasmas





Longitudinal (thru target) interferogram showing CH irradiated at 10^{12} Wcm^{-2} by 300 ps pulse



Phase shift vs time during irradiation

- Interferometry at 21.2 nm probing longitudinally
- Phase shift drops below 0 →

'non-plasma' refractive index associated with C^+

Exp. at PALS, Czech Republic

3820 OPTICS LETTERS / Vol. 35, No. 22 / November 15, 2010

Extreme ultraviolet interferometry of warm dense matter in laser plasmas

L. M. R. Gartside,[1,*] G. J. Tallents,[1] A. K. Rossall,[1] E. Wagenaars,[1] D. S. Whittaker,[1] M. Kozlová,[2] J. Nejdl,[2,3] M. Sawicka,[2,3] J. Polan,[2] M. Kalal,[3] and B. Rus[2]

Modelling XFEL heating of solid targets

- Volumetric heating – expansion occurs on 10 ps timescale
- Photo-ionisation/Auger decay dominate – other collisional and radiative process occur at much slower rates
- Rate modelling opposite assumes electrons are thermal and uses modified Lotz formula

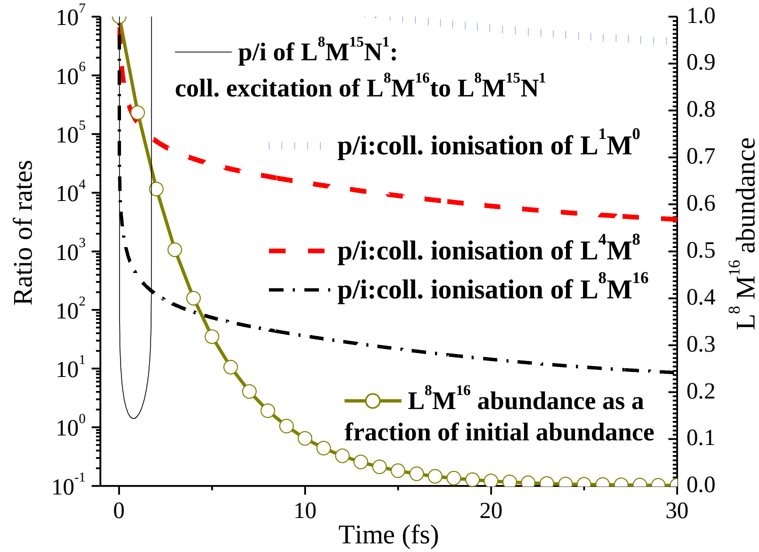
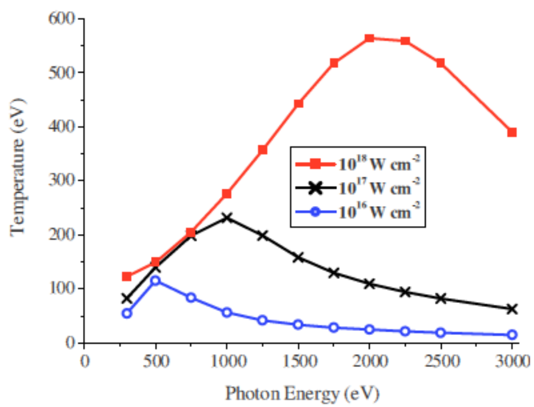
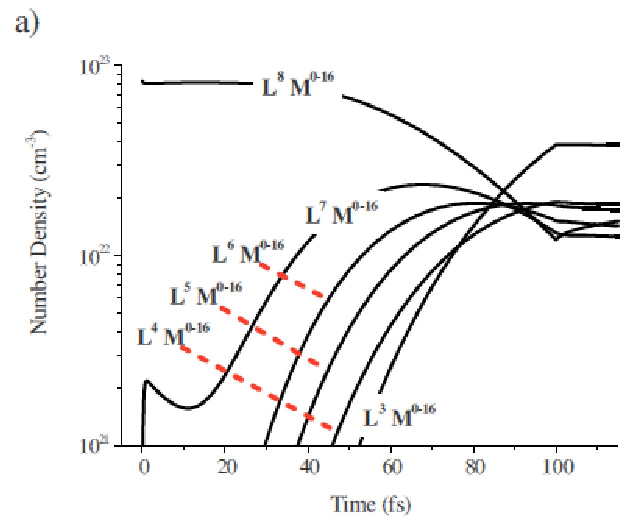


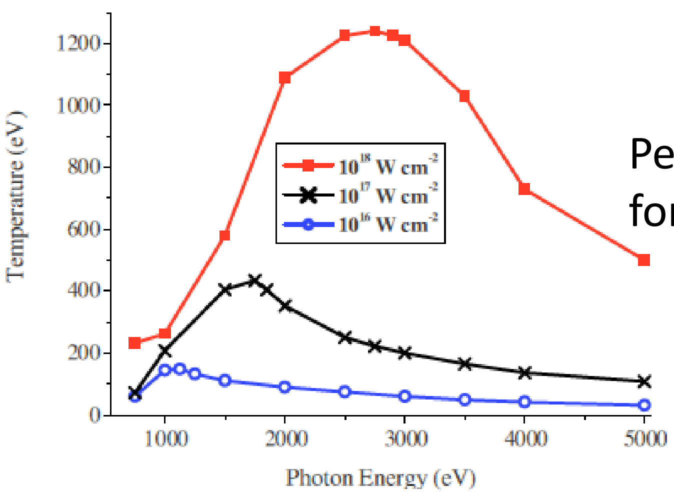
Photo-ionisation of iron dominates collisional ionisation by at least an order-of-magnitude at 10^{18} Wcm^{-2}. Figure shows the rates of photo-Ionisation/collisional ionisation of different states for 3 keV photons

Predictions of temperatures in XFEL heating (after LTE equilibration)



Peak temperatures for carbon targets





Peak temperatures for iron targets

Time dependent populations of iron and carbon upon XFEL irradiation are modelled. Result for 1.75 keV photons at 10^{17} Wcm^{-2} are shown

PHYSICS OF PLASMAS **18**, 013105 (2011)

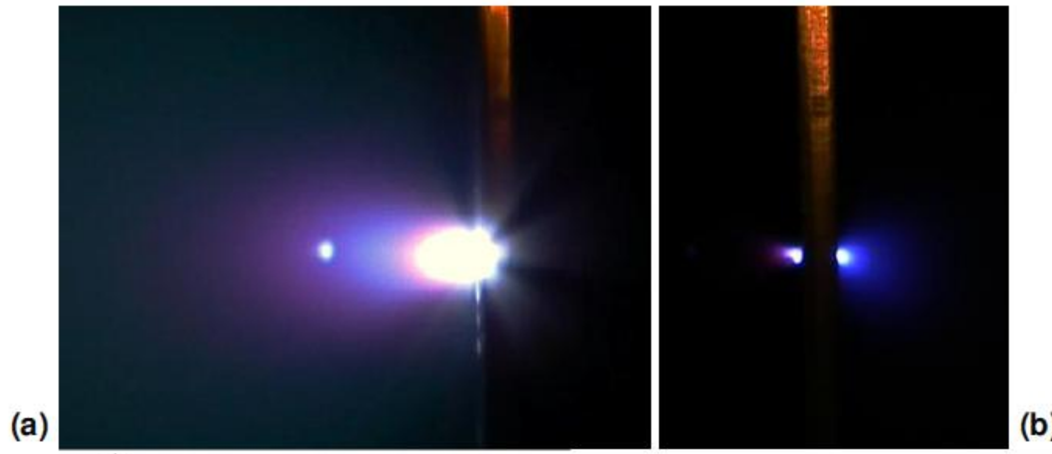
Temperatures following x-ray free-electron-laser heating of thin low- and medium-*Z* solid targets

D. S. Whittaker,[a] E. Wagenaars, and G. J. Tallents
Department of Physics, University of York, York YO10 5DD, United Kingdom

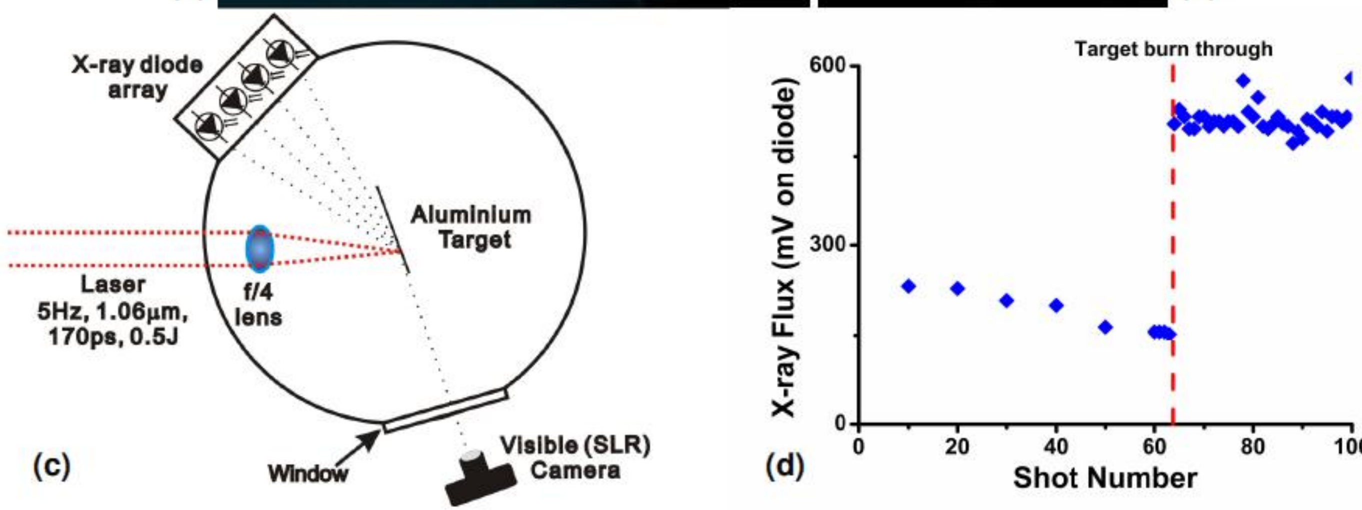
(Received 1 August 2010; accepted 4 January 2011; published online 28 January 2011;

Local laser-plasma at York shows 4x increase of x-ray flux focussed into target ‘hole’.

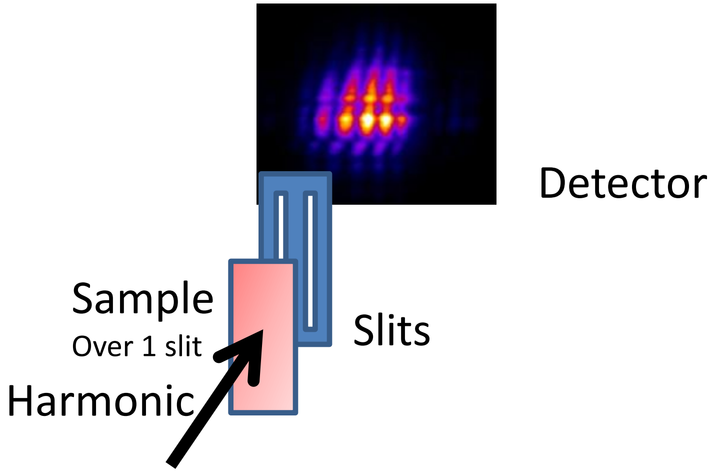
Image of laser scatter and emitted light onto plane and ‘hole’ targets



Experimental set-up and the x-ray flux at 5 keV as a hole is created in the 2 mm thick target



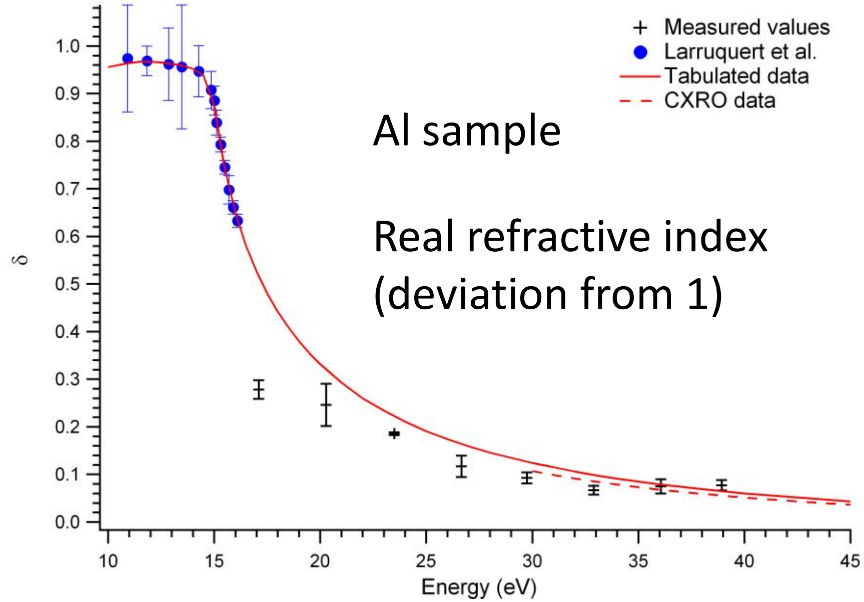
Double slit interferometry to measure EUV refractive indices of solids using high harmonics

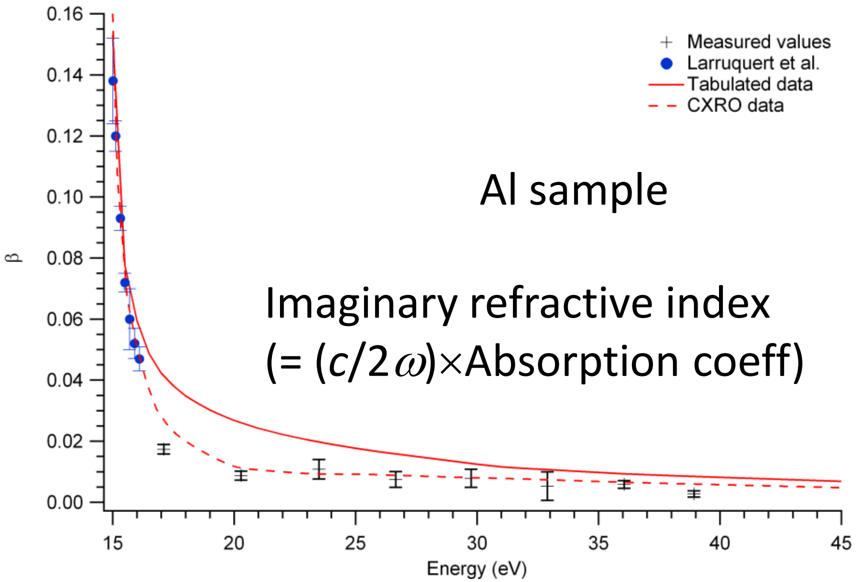


- Real and imaginary parts of Aluminium refractive index measured

$$n(\omega) = 1 - \delta(\omega) + i\beta(\omega)$$

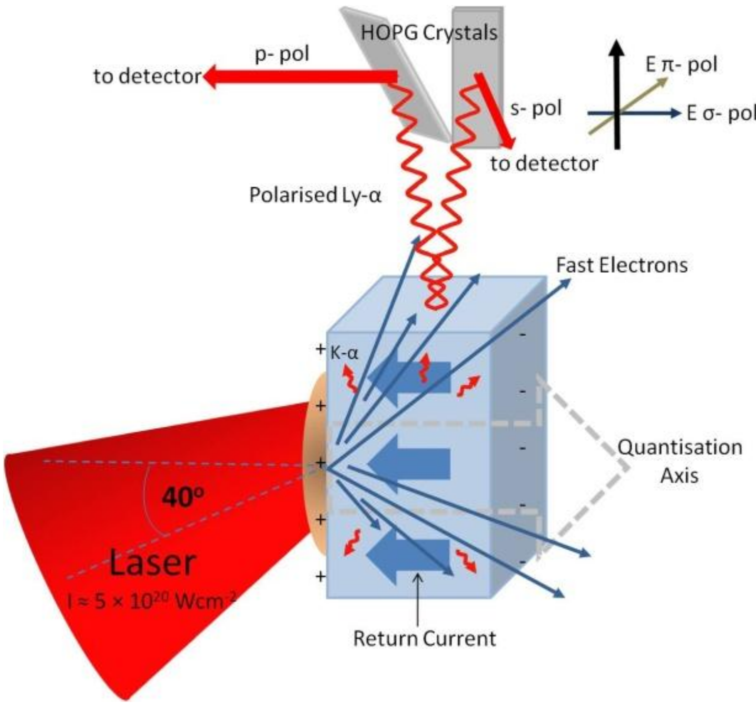
- Measurements of EUV refractive indices from 17 – 40 eV for Iron and Aluminium samples.
- Double slit interferometry used to measure δ from phase shift and β from fringe visibility.
- Results compared to previous experimental work and CXRO database values.
- Potential for further work on laser heated materials.

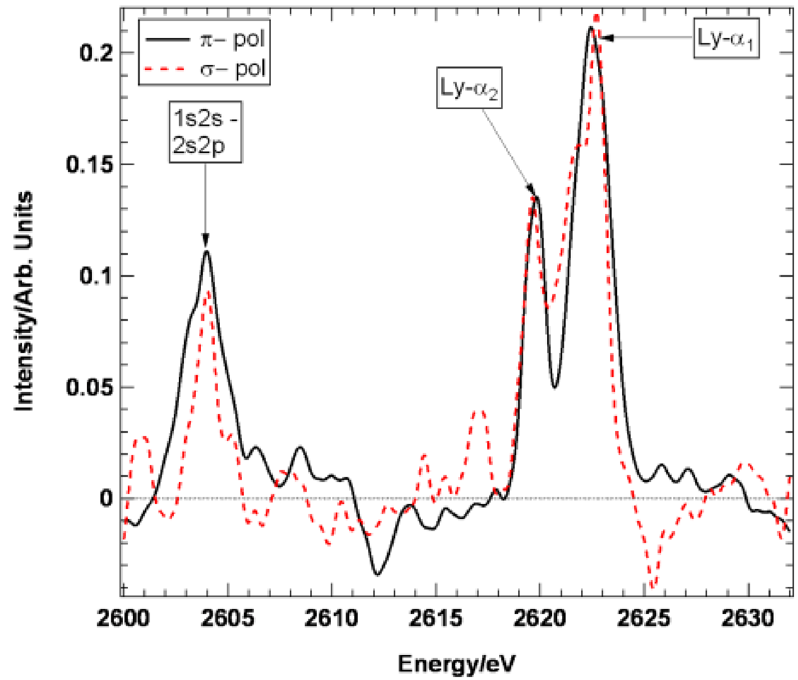




Undertaken at ARTEMIS RAL

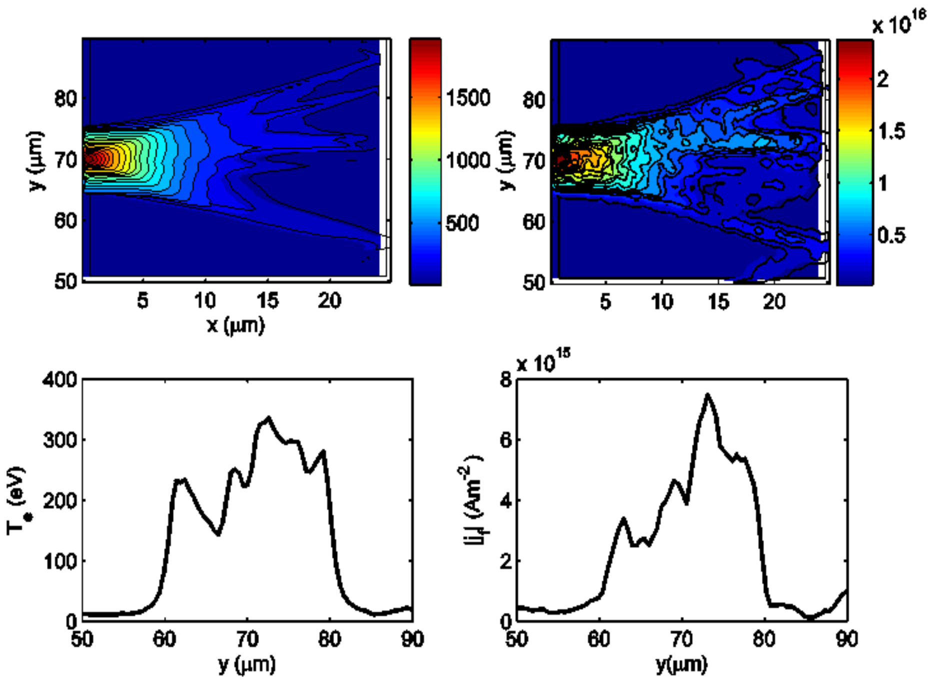
Return current – beam component





- Vulcan TAP experiments at 5×10^{20} W cm^{-2}
- Employed polarisation spectroscopy to study Ly-α of S (Z=16) and Ni (Z=28) at 2.6 keV and 8.1 keV
- Sulphur (lower excitation energy) records large positive (+0.22) polarisation, Ni Ly-α records negative polarisation (-0.5)

Return current beam component is exists

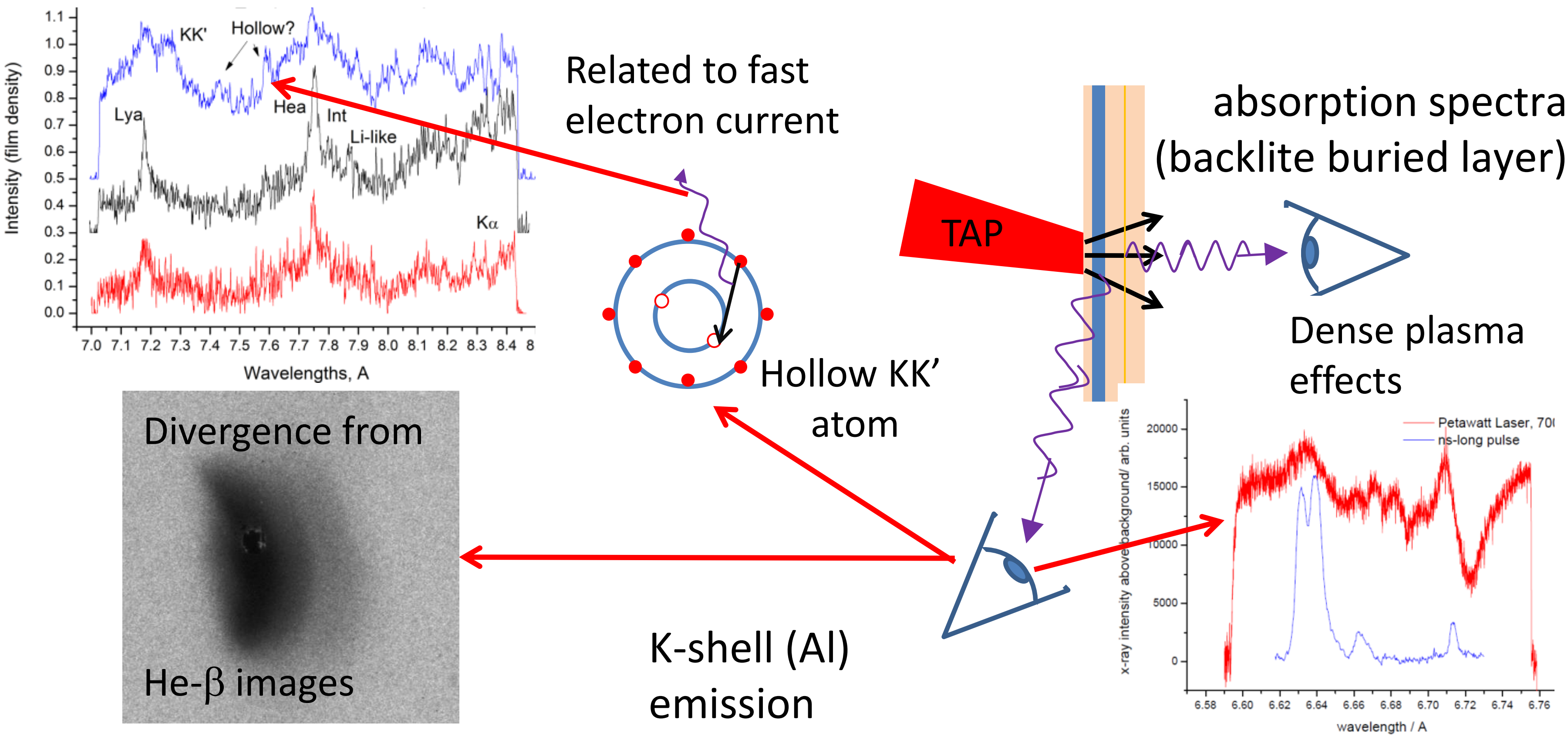


k_BT_b (eV)	k_BT_{rc} (eV)	P
200	400	+0.07
200	500	+0.12
200	600	+0.14

k_BT_b (eV)	k_BT_{rc} (eV)	P
600	2400	+0.007
800	3200	+0.003
1400	5600	+0.001
2000	8000	+0.0007

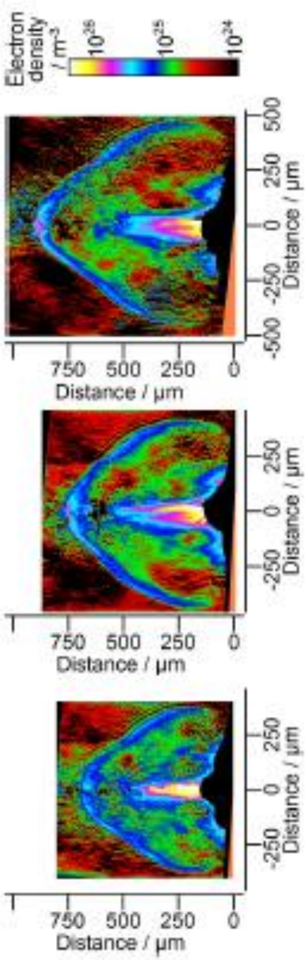
- Interpretation uses combination of plasma (ZEPHYROS, Alex Robinson, CLF) and sub-level atomic kinetics (POLAR, Peter Hakel, Reno)
- Return current temperature: Isotropic part ~ 200eV, beam part ~600eV
- Unambiguous indication of return current EDF structure

Currents, heating and beam divergence



- Current TAP experiment (AWE, Strathclyde, Jena, RAS)
  - employ high luminosity, imaging spectrometers
- Extending buried layer techniques to measure fast electron beam current and divergence, and deep target resistive heating

Laboratory astro (shocks and jets)

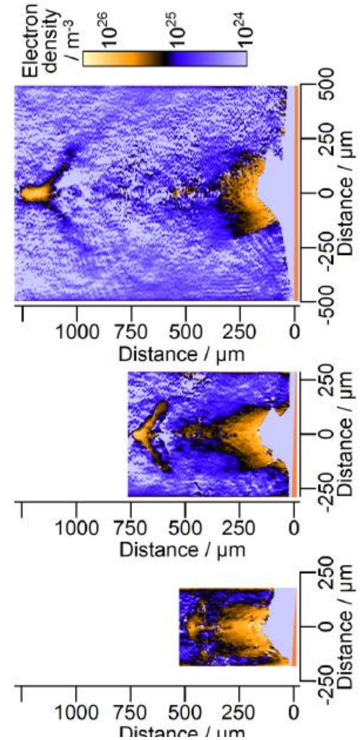


Jets generated
on Astra (He 100mb)

5 ns

4 ns

3 ns



Jets generated
on Astra (in Xe 4mb)

10 ns

5 ns

3 ns

- Plasma jets – radiative hydrodynamics
- Particle (CR) acceleration at shocks: 3 facets
  - collisionless shocks (MHD plasma)
  - wave-particle (including B field generation)
  - supra-thermal particles (accelerating particles)

Summary

- We pursue a wide range of IFE related activities at the University of York
- I have attempted to give you some feel for the breadth of our activities
- Thank you for your attention!