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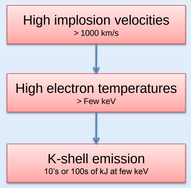
Implosion and Stagnation Dynamics of Large Diameter Wire Array Radiation Sources on Z

D.J. Ampleford *et al.*

Large diameter z-pinches as multi-keV RES sources

- **Bright multi-keV sources are valuable for radiation effects experiments[1]**
  - ♦ See talks by B. Jones, N. Moore, T. Flanagan
  - ♦ K-shell emitting wire arrays have historically been shown to be efficient multi-keV sources
  - ♦ Fully understanding the implosion dynamics facilitates optimization and control
- **Large temperatures are required to produce K-shell emission efficiently[2]**



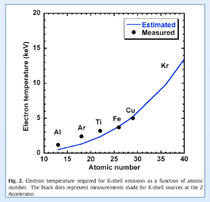
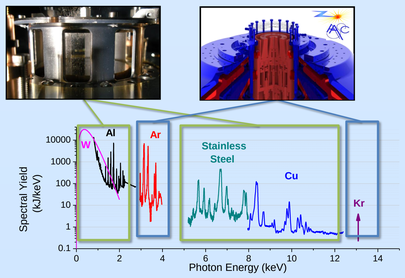
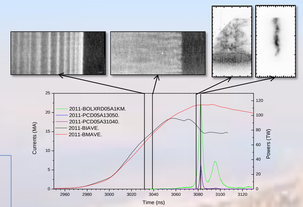


Fig. 2. Electron temperature required for K-shell emission as a function of atomic number. The black dots represent measurements made for K-shell sources at the Z Accelerator.

- **Different approaches are used to provide different photon energies**
  - **Wire array z-pinches (Al, SS, Cu)**
  - **Gas puffs (Ar, Kr) [see C. Jennings poster]**



- **Wire array implosion consists of many phases**
  - **Ablation**
  - **Implosion**
  - **Stagnation**



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References
1. **D.J. Ampleford et al.,** HEART conference 2012; **D.J. Ampleford et al.,** submitted to Journal of Rad. Effects Research & Eng.
2. **C.A. Coverdale et al.,** High Energy Density Phys. 8, 143 (2010)
3. **B. Jones et al.,** Rev. Sci. Intrum. 79, 10E906 (2008)
4. **D.J. Ampleford et al.,** Int. Conf. on Plasma Science (2011)
5. **C. Jennings et al.,** Dense Z Pinch conference (2011)
6. **S.B. Hansen et al.,** High Energy Density Phys. 7, 303 (2011)
7. **B. Jones et al.,** Phys. Rev. E 84, 056408 (2011)
8. **D.J. Ampleford et al,** Int. Conf. on Plasma Science (2010)
9. **D.J. Ampleford et al,** Dense Z Pinch conference (2011)
10. **J.P. Apruzese et al.,** J. Quant. Spectrosc. Rad. Transf. 57, 41 (1997)
11. **D.J. Ampleford et al.,** in preparation for Phys. Plasmas
12. **D.J. Ampleford et al.,** Int. Conf. on Plasma Science (2012)

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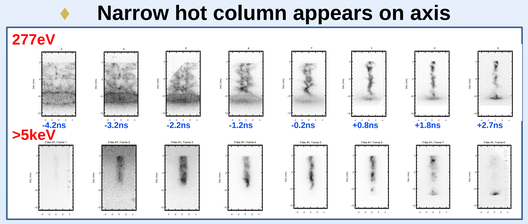
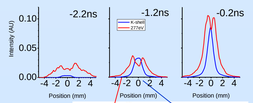
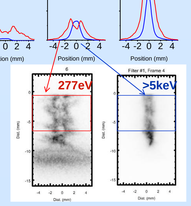
Ablation and implosion dynamics

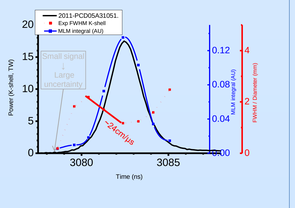
- **Self-emission imaging[3] shows evolution of implosion[4]**
  - **277eV shows bulk mass**
    - ♦ Pinhole image using monochromatic mirror
    - ♦ Hollow shell converges on axes
  - **>5keV shows K-shell emitting region**
    - ♦ Filtered pinhole image
    - ♦ Narrow hot column appears on axis



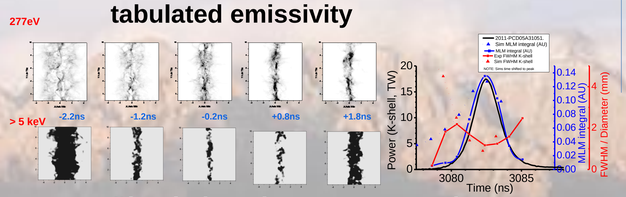
- **Detailed analysis of images identifies key details of dynamics[4]**
  - **Harder emission (blue) is surrounded by bulk of mass (red)**
    - ♦ Consistent with leading edge being heated
  - **K-shell column FWHM decreases**
    - ♦ Either compression or shock propagation







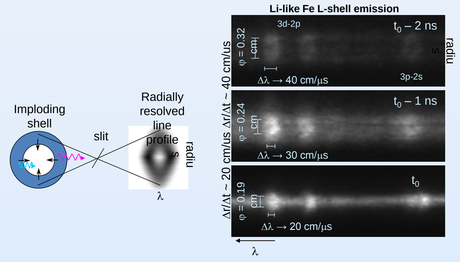
- **MHD simulations recover similar dynamics[5] [see C. Jennings poster]**
  - **Gorgon 3D MHD codes coupled to tabulated emissivity**



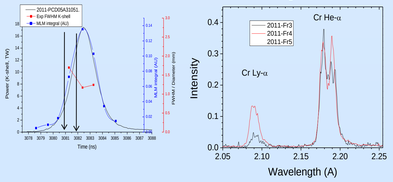
- **Simulation shows compression**
- **K-shell emission occurs at leading edge**

Stagnation of plasma on the axis

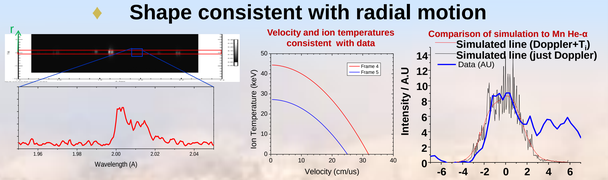
- **Spectroscopy measures velocity up to stagnation[4,6,7]**
  - **Time- and space-resolved spectrometer looking at Fe L-shell**
  - **Doppler split determines velocity**



  - **Deceleration from ~40 to ~20cm/us in the few ns before peak x-rays**
- **K-shell spectroscopy shows heating during compression**
  - **Ly-α is increasing compared to He-α**
  - **Consistent with rise in temperature**



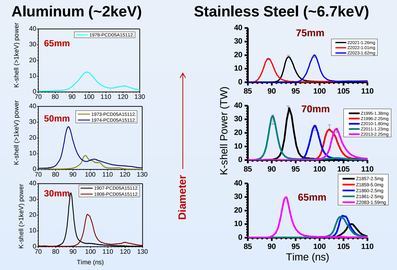
- **Width of optically-thin K-shell lines set limit on ion temperature**
  - **Narrow Mn He-α limits T_i < 30keV**
    - ♦ Any radial motion will lower this
    - ♦ Shape consistent with radial motion



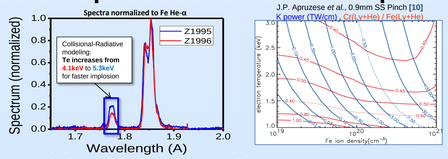
  - **Gorgon simulated diagnostics**
    - ♦ **Line specific emissivity with Doppler**
      - **No Satellites**
    - ♦ **Shows similar width to data, and mostly from bulk motion not ion temperature**

Optimization of K-shell yield

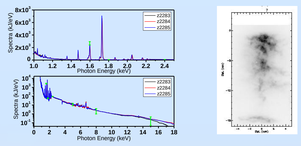
- **Detailed source optimization experiments performed[8,9]**
  - **Mass and diameter variations identify optimum for each material**



- **MHD, atomic physics and spectroscopy guide development[8]**
  - **Hotter pinch seen for faster implosion**



- **Considerable free-bound continuum is radiated by Al implosion**
  - **Characterized on Z for 0.8-20keV**
  - **Shape very reproducible**
    - ♦ **Pinhole image shows very unstable pinch**



- **Detailed understanding has enabled[1]**
  - **Stainless Steel source[11]**
    - ♦ **Radiates ~73kJ at >5keV**
    - ♦ **Used in 18 dedicated RES tests**
  - **Al source[12]**
    - ♦ **Radiates ~270kJ at >1keV**
    - ♦ **Used in 12 dedicated RES tests**
- **Planning is underway for 13keV and >15keV sources**

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