Film characterization of Agfa D7 and D8 x-ray film using a multiple anode x-ray source

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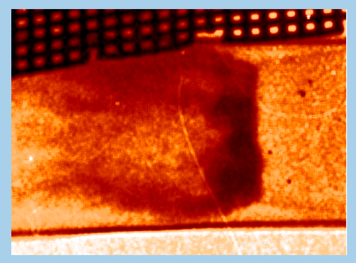
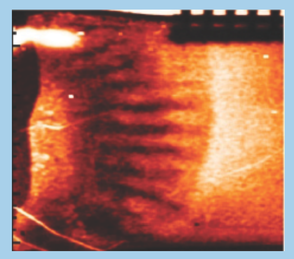
Implementation of X-ray radiographs in High-Energy-Density Shock Experiments

Laser facilities that are capable of producing multi kilo-joule nano-second laser pulses have provided a platform for in depth studies of matter in the high-energy-density (HED) regime. As this regime requires temperatures in the tens to hundreds of eV range, the diagnostics used are often standoff diagnostics that will not be damaged during the experiment. A useful diagnostic that can help determine the structure of an HED shock is the X-ray radiograph.





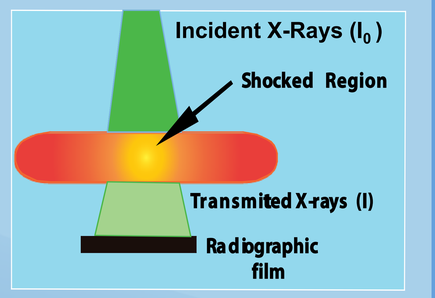
Radiographs allow for HED shocks to be analyzed including structure development and density

Calculating plasma density using radiographs

As X-rays pass through the shocked region they are scattered and absorbed by the plasma, with denser regions absorbing/scattering more. If the composition of the plasma is known the density can be determined by using the Lambert-Beer law and solving for density

$$\rho\mu L = \ln(I/I_0)$$

I = Intensity
I_0= Initial Intensity
L = thickness of plasma
ρ= plasma density
μ= mass attenuation coefficient

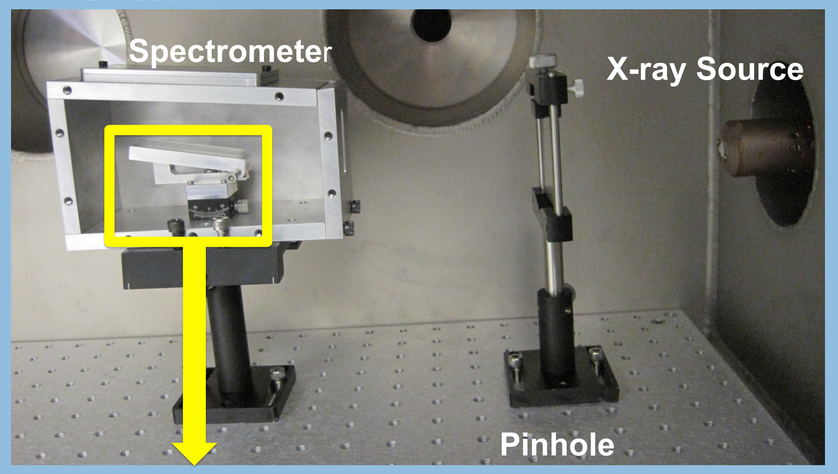


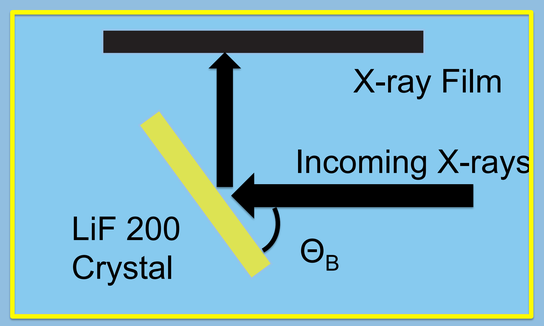
I and I_0 are determined by film characterization

- Each film reacts differently to different energies and intensities of x-rays (e.g. saturation)
- The film that was most often used and well calibrated, Kodak DEF is no longer in production
- The newer films Agfa D7 and D8 need this calibration performed across various energies and intensities
- Knowing film response gives a quantitative value of I and I_0 allowing the plasma density to be determined

Experimental Setup

- A multi-photon energy, variable emission-current x-ray source allows for flexibility in fluxes and energies tested.
- The X-ray source has a wide dispersion so a pinhole is implemented to narrow the beam
- A crystal spectrometer separates the various photon energies from the source onto the film using Bragg Diffraction.





Bragg Diffraction Criteria

$n\lambda = 2d\sin(\theta_B)$

λ= Photon Wavelength

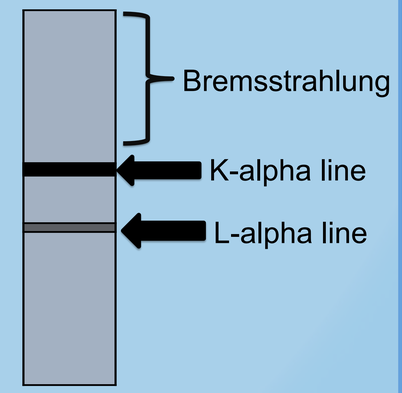
d = Crystal Spacing

θ_B=Bragg Angle

Analysis of Film

- Each film exposure will be timed and the flux at the point of the film can be calculated using the known intensity of source. This provides the number of incident photons.
- A dark line on the film will indicate the dominant K-alpha line of the particular anode used. This provides a region where the energy of the photons is well determined.
- Using a densitometer the Optical Density (i.e. darkness) of the film is quantified.
- Repeating this procedure for multiple photon energies and intensities, a response curve for the film can be created
- The first anodes used will be Copper (8.0keV) and Chromium (5.4keV)

Expected appearance of the film. The X-ray source generates a range of energies due to Bremsstrahlung radiation but K-alpha lines are always much stronger.



Future Work

Once initial experiments are completed using Copper and Chromium anodes, we will obtain other crystals to allow for characterization using lower energy sources like Magnesium and Aluminum.

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