Final Focus Ion Beam Intensity from Tungsten Foil Calorimeter and Scintillator in NDCX-I*

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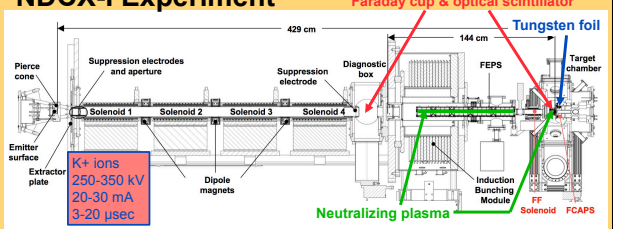
ABSTRACT: Laboratory high energy density experiments using ion beam drivers rely upon the delivery of high-current, high-brightness ion beams with high peak intensity onto planar targets. Solid-state optical scintillators are typically used to measure the ion beam spatial profile but they display dose-dependent degradation and aging effects. These effects produce uncertainties and limit the accuracy of measuring peak beam intensities delivered to the target. For beam tuning and characterizing the incident beam intensity, we have developed a cross-calibrating diagnostic suite extends the upper limit of measurable peak intensity dynamic range. Absolute intensity calibration is obtained with a 3 μm thick tungsten foil calorimeter and streak-spectrometer. We present experimental evidence for peak intensity measures in excess of 400 kW/cm^2 using a ~300 kV, ~25 mA, 5-20 μsec K^{+1} beam driver. Radiative models and thermal diffusion effects are discussed as they affect temporal and spatial resolution of beam intensity profiles.

NDCX-I Experiment



Scintillators are a standard component in transverse beam profiling diagnostics:
- Linear response over large dynamic range.
- Can be relatively resistant to dose dependent darkening and aging effects at low intensities.
- May suffer saturation and deviation from linearity at high intensities.

Calorimeters can be complementary diagnostics:
- Can tolerate higher doses
- Highly nonlinear response to irradiation intensity.
- Intense source of optical radiation.
- Good time response in 100ns to ~10μsec range.

One-dimensional heat equation

The equation is solved to determine the tungsten foil calorimeter temperature response to prescribed beam flux.

$$\delta_{th} = 2\sqrt{\kappa t}$$

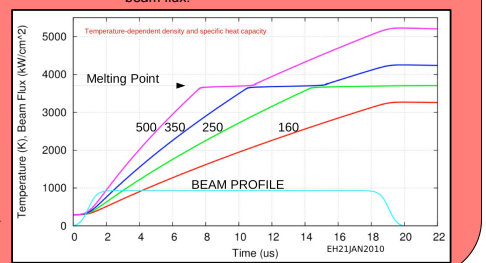
The thermal diffusion time set the appropriate time and length scales and must be rationalized with the beam pulse duration, foil thickness, and transverse optical resolution.

The 1D heat conduction equation describes the longitudinal flow of heat in the system, due to temperature gradients, thermal conductivity, and heat sources.

$$\rho c_p \partial_t T = \partial_x \left(K \partial_x T \right) + S(x,t)$$

The boundary conditions describe the relevant energy fluxes.

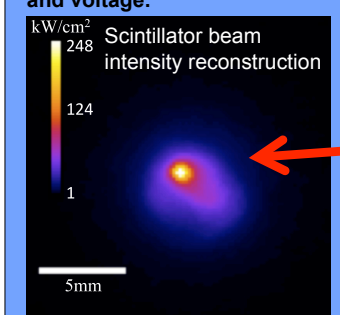
$$\left(K \partial_x T \right)_{U,D} = F_{U,D}(T)$$



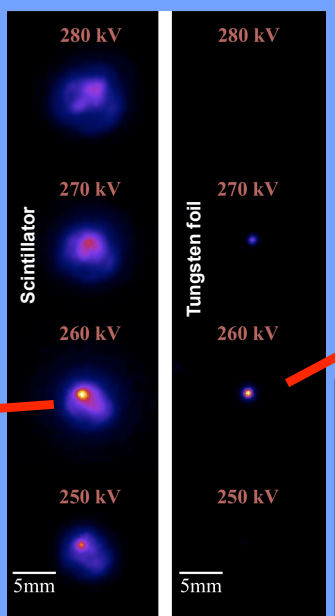
Scintillator Beam Profile and Tungsten Foil Calorimeter

The K+ beams were imaged at the target plane onto both the alumina scintillator and tungsten foils.

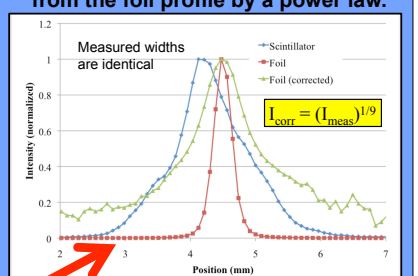
The beam intensity profile is derived by normalizing the scintillator profile against the measured beam current and voltage.



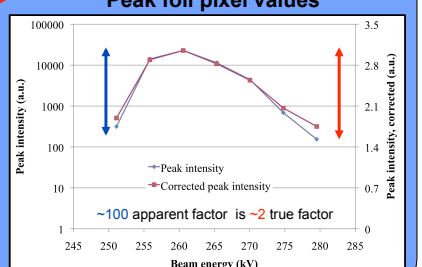
Saturation in scintillator may affect the measurement of the peak values.



The beam distribution is recovered from the foil profile by a power law.



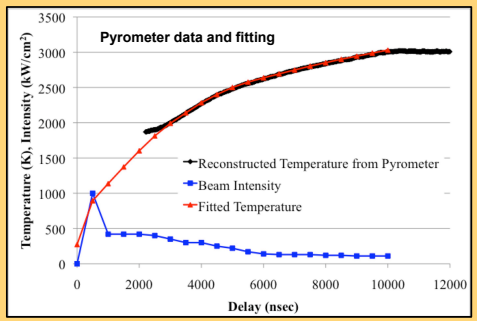
Peak foil pixel values

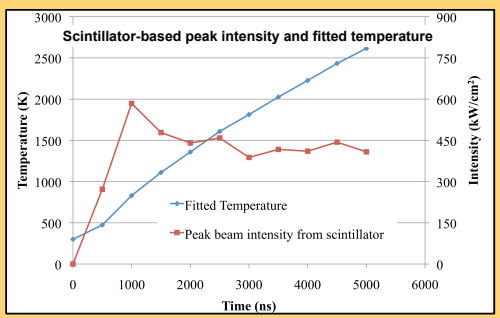


Temperature reconstruction and beam intensity

- Streak-spectrometer records 650nm radiation.
- Reconstruct foil temperature.
- Beam intensity history is generated.
- Heat equation is solved to match the calculated temperature with the reconstructed pyrometer data.

Time Interval (μsec)	Average Beam Intensity (kW/cm^2)
0.0 – 4.0	430
4.0 – 10.0	133
0.0 – 10.0	260





Empirical cross-calibration factor ~2 brings temperature rise into agreement with pyrometer measurement.

Average beam intensity 430 kW/cm^2 matches estimate from pyrometry data.