Exploring Mechanisms of Hot Electron Generation

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In Collaboration With

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Abstract

The generation of hot electrons is of great interest in a number of fields including fast ignition and medical X-rays [1]. At present, the exact mechanisms through which hot electrons can best be generated are still a subject of some debate. Two possible mechanisms are resonance absorption [2] and ponderomotive ($\mathbf{j} \times \mathbf{B}$) heating [3]. This experiment examines and compares these two mechanisms of hot electron generation to determine which are most prevalent in which circumstances. The main way this is be done is by observing coherent transition radiation (CTR) from an irradiated target at two different wavelengths. Past results have suggested that resonance absorption will mainly cause CTR at the laser wavelength, ω [4], while CTR at 2ω is indicative of $\mathbf{j} \times \mathbf{B}$ heating [5]. This is the first phase of the development of a research plan to study electron transport in flat targets as well as in cone targets, both in non magnetized and magnetized environments.

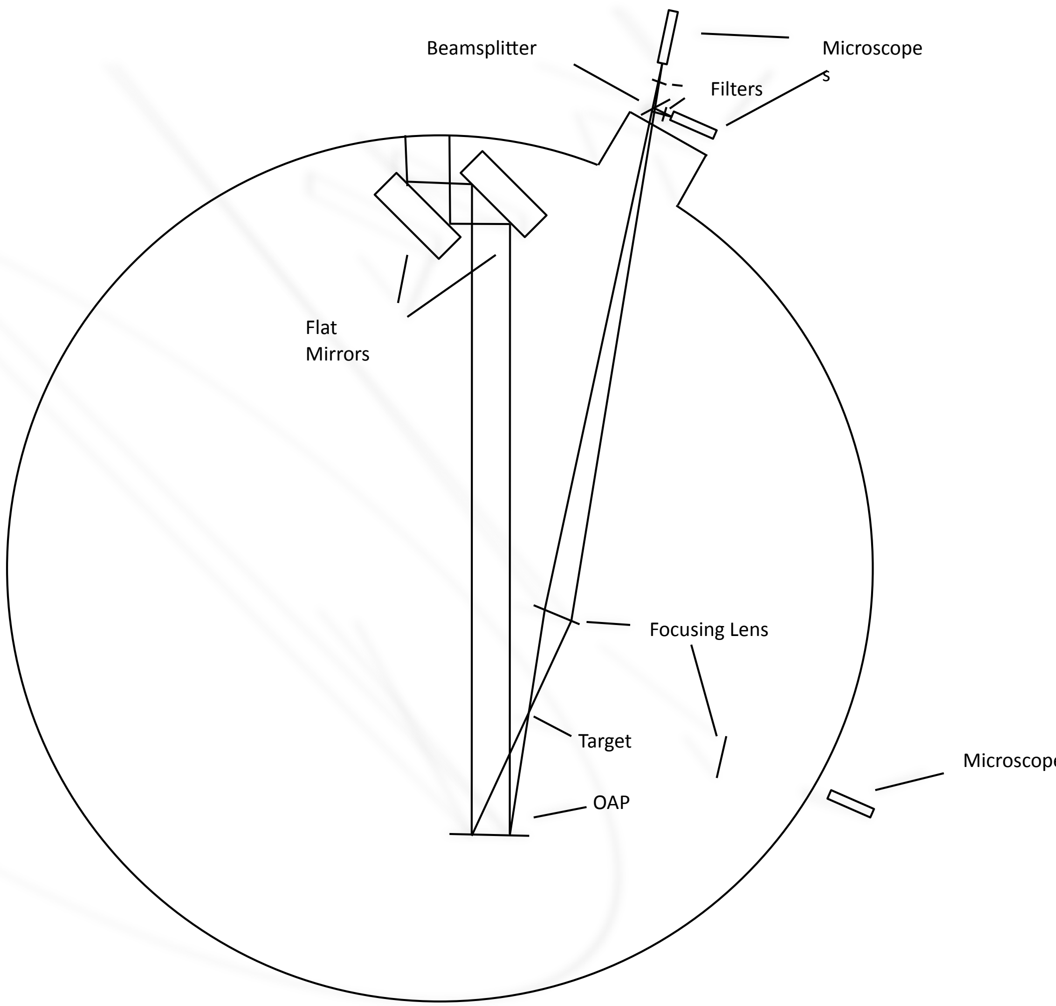
Theory of CTR

- Transition radiation is generated when charged particles (such as electrons) cross a dialectric boundary [6].
- In general, the spectrum of transition radiation is flat over a wide range [1].
- However, certain effects will cause electrons to form into bunches at specified intervals [7].
- Transition radiation at the bunch interval wavelength will add coherently, producing coherent transition radiation [1].
- Resonance absorption will cause electrons to bunch at ω intervals, producing CTR at ω [4].
- ($\mathbf{j} \times \mathbf{B}$) heating will cause electrons to bunch at 2ω intervals, producing CTR at 2ω [5].

Lasers Used

- Shots were done with the Leopard Laser at NTF and the GHOST laser at UT Austin.
- Leopard Laser: Pulse Energy 7-11 J
  Pulse Duration ~350 fs
  Wavelength λ_0 = 1056 nm, $\Delta\lambda$ = 6 nm
  Shot Cycle ~1 hour
  Spot Diameter 20 – 30 µm
- GHOST Laser: Pulse Energy 2-3 J
  Wavelength λ_0 = 1064 nm
  Shot Cycle ~2 minutes

Setup at NTF



Beamsplitter
Microscope
s
Filters
Flat
Mirrors
Focusing Lens
Target
OAP
Microscope

Leopard Shot Procedure

- A camera was set up behind the target to use for alignment and for imaging CTR.
- Narrow bandpass interference filters at ω and 2ω were used to filter light on the camera.
- An off-axis parabola was used to focus the beam, and positioned so the focal spot of the beam was right at the focus of the camera.
- Another camera was placed to be focused on the same spot as the first camera, but exactly perpendicular to it.
- This gave us very precise positioning on the target and the ability to place the target very close to best focus.
- The original plan was to use a beamsplitter to get ω and 2ω on the same shot, but this proved not to be feasible as we were unable to get the intensity required through the beamsplitter.
- A polarizer was placed on the camera to see if there were any noticeable polarization effects on the CTR, but none were observed.
- Targets on Leopard were shot at slightly off normal incidence.

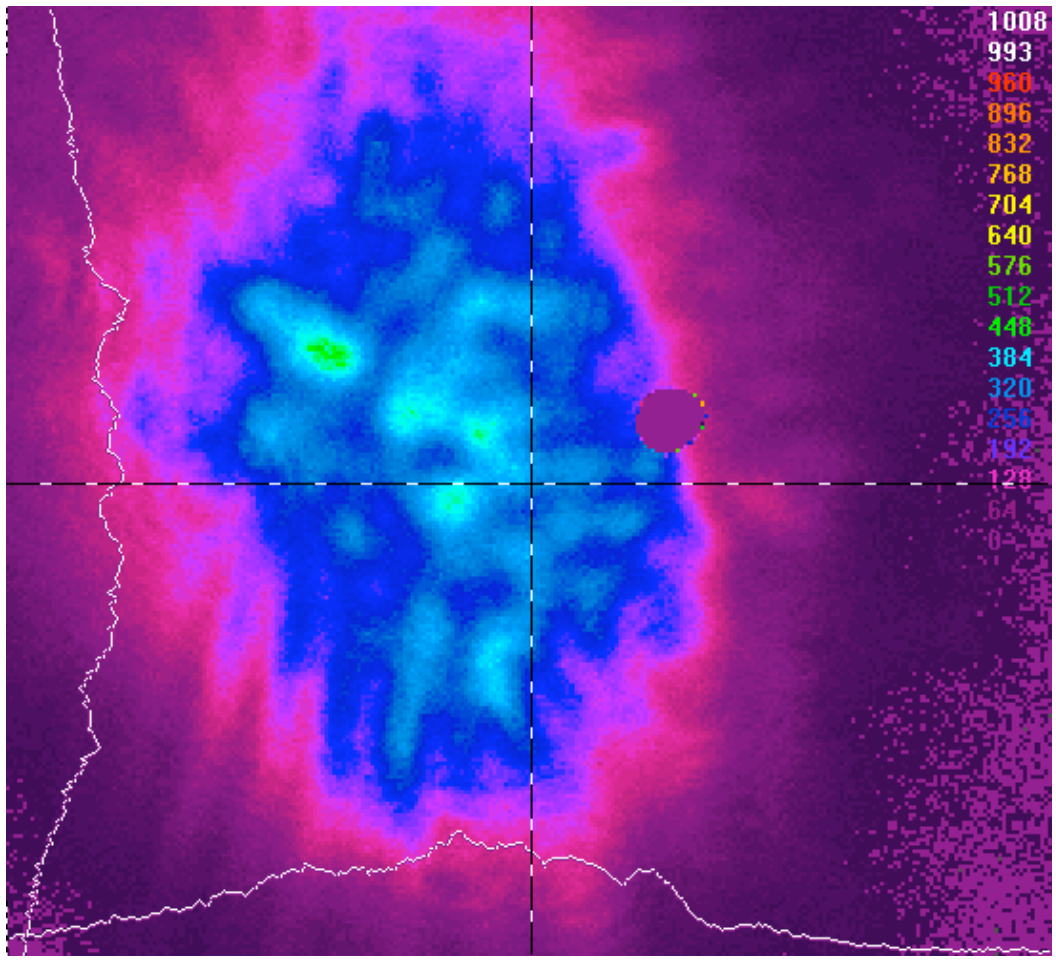
GHOST Shot Procedure

- A camera was set up behind the target to use for imaging CTR.
- Narrow bandpass interference filters at ω and 2ω were used to filter light on the camera.
- An off-axis parabola was used to focus the beam. A lens was placed in the target chamber to focus on the camera. The focusing lens was set up to focus on the focal spot of the parabola.
- Another camera was placed behind the target and to the side to image light scattered off the target.
- A HeNe was used to illuminate the target and align it at best focus.
- The original plan was to use an SEM tip placed on the target to align the target at best focus, but this proved to be too imprecise to get good CTR.
- The backscattering camera was able to give more precise alignment, but this required a search for best focus through a large number of shots.
- Targets on GHOST were shot at 45° incidence.

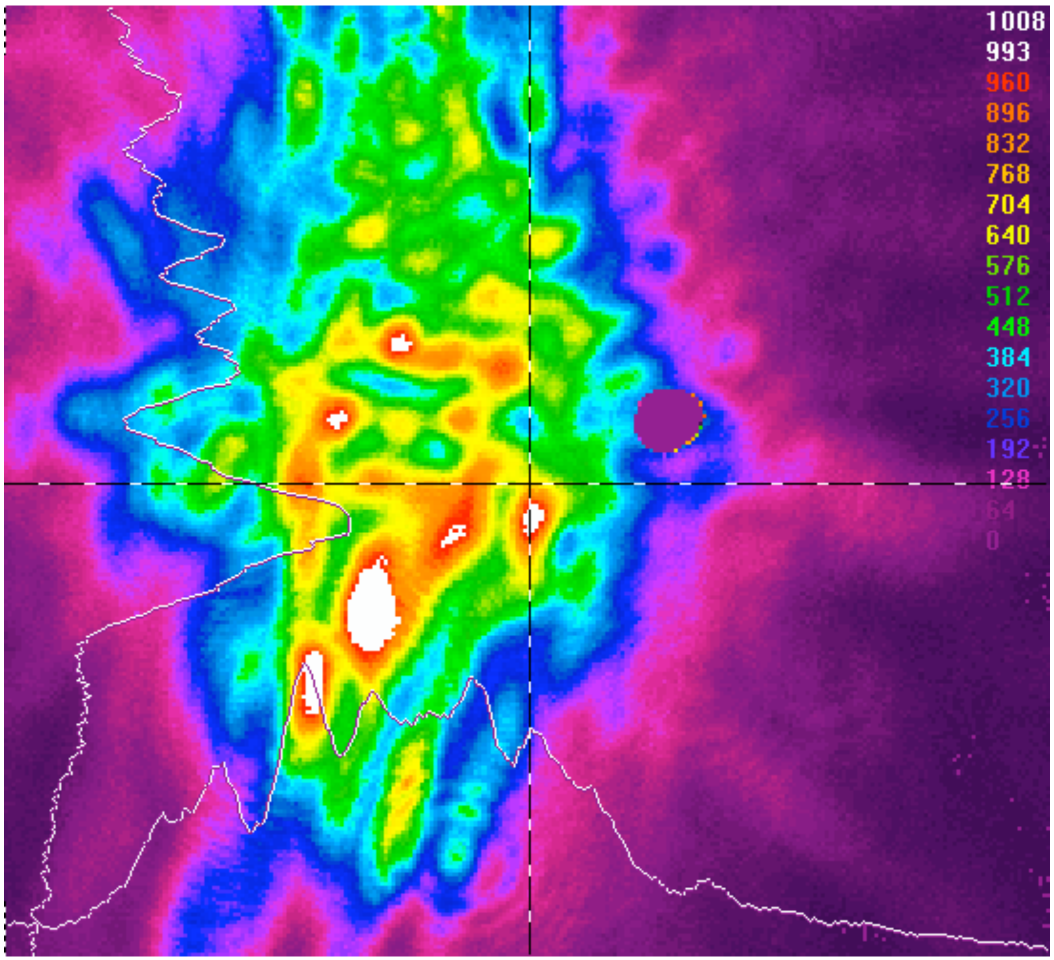
Results

- On the Leopard shots, we observed CTR only at ω.
- At normal incidence, 2ω CTR, if it exists, is at least three orders of magnitude dimmer than at ω.
- This would seem to suggest the primary mode of hot electron generation is at normal incidenceresonance absorption, but more research needs to be done here to draw a firm conclusion.
- No effects of polarization were observed.
- CTR intensity seems to be inversely proportional to target thickness, in agreement with [1]. CTR was also observed to be inversely proportional to the Z of the target material.
- The most striking CTR was observed for thin targets at low Z.

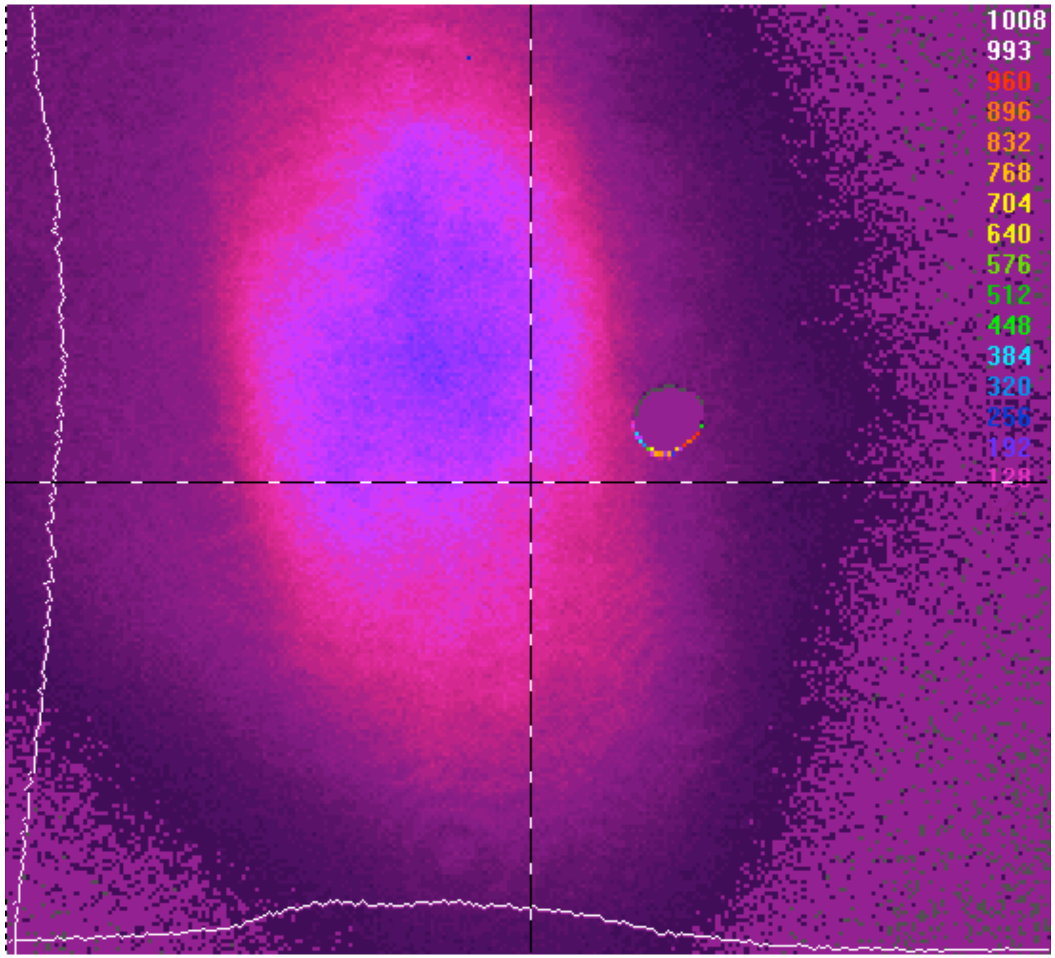
Mo 12.5 μm on GHOST



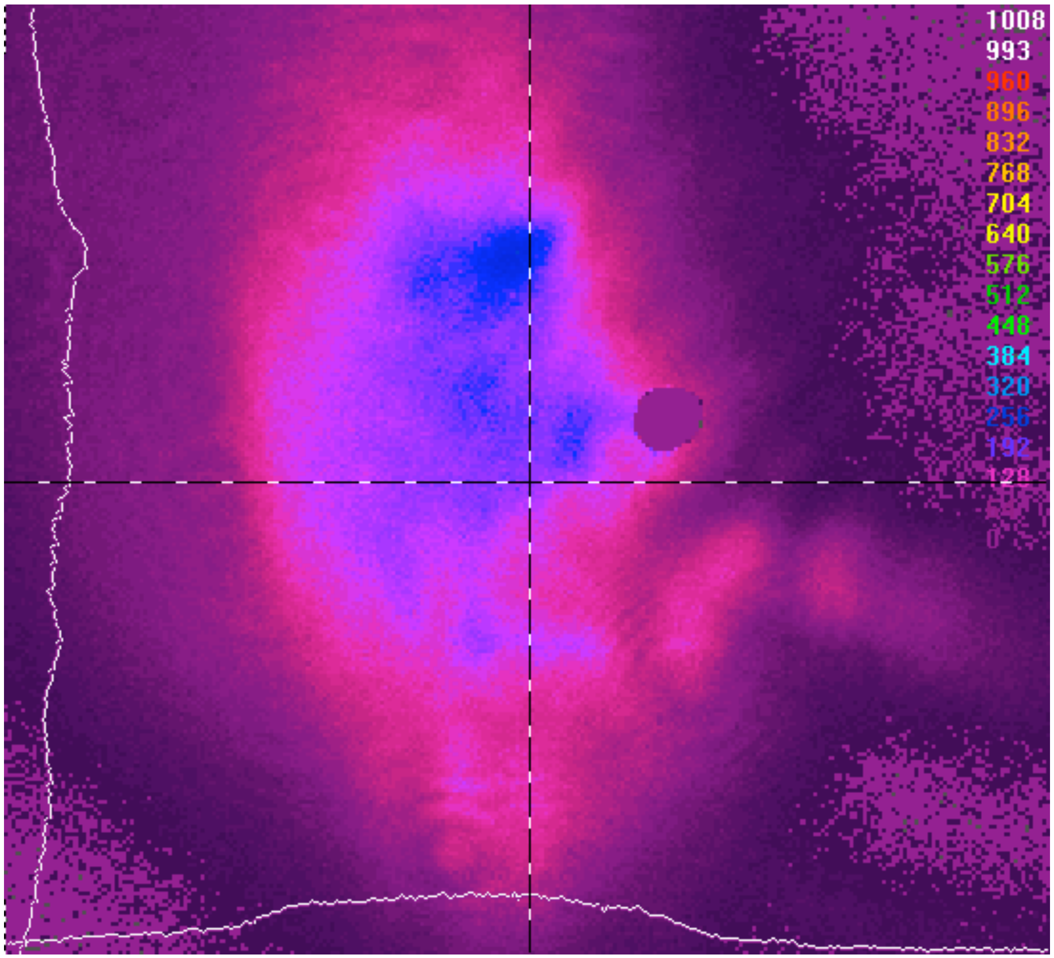
Mo 4 μm on GHOST



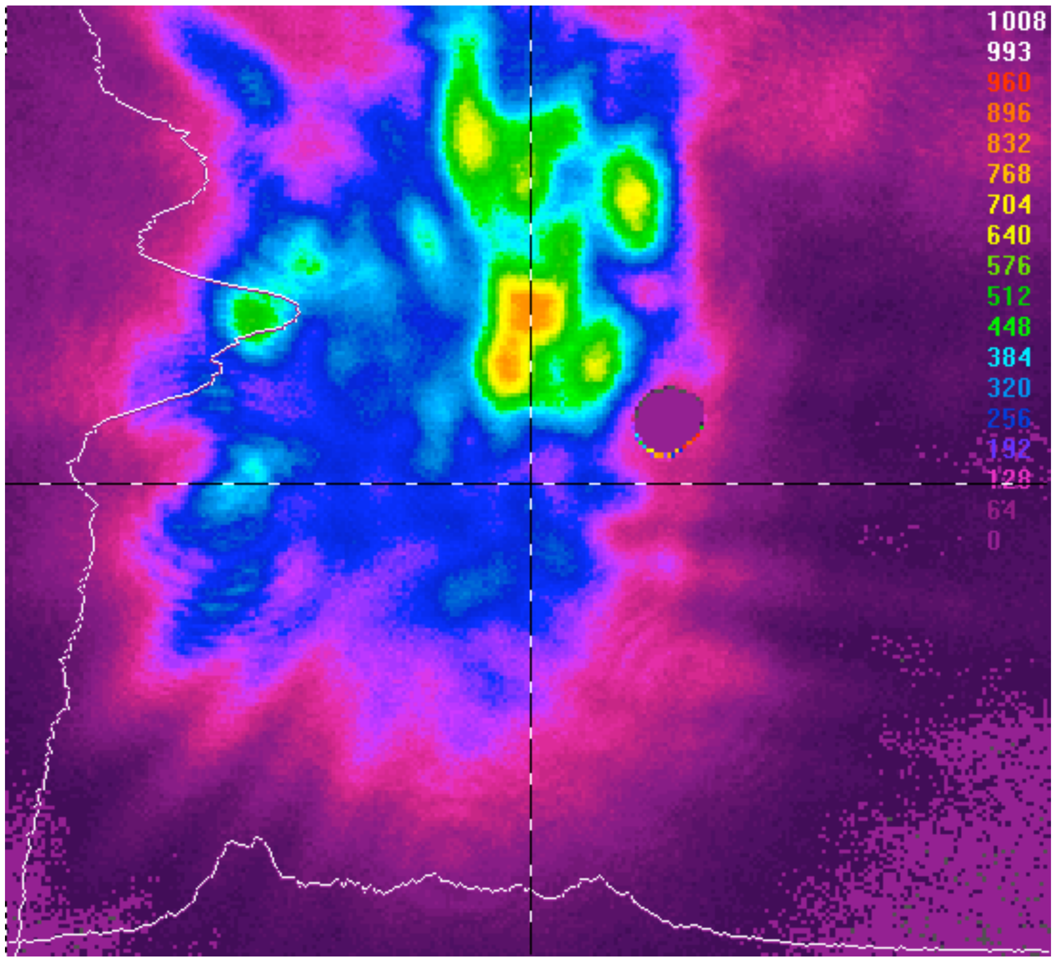
W 12.5 μm on GHOST



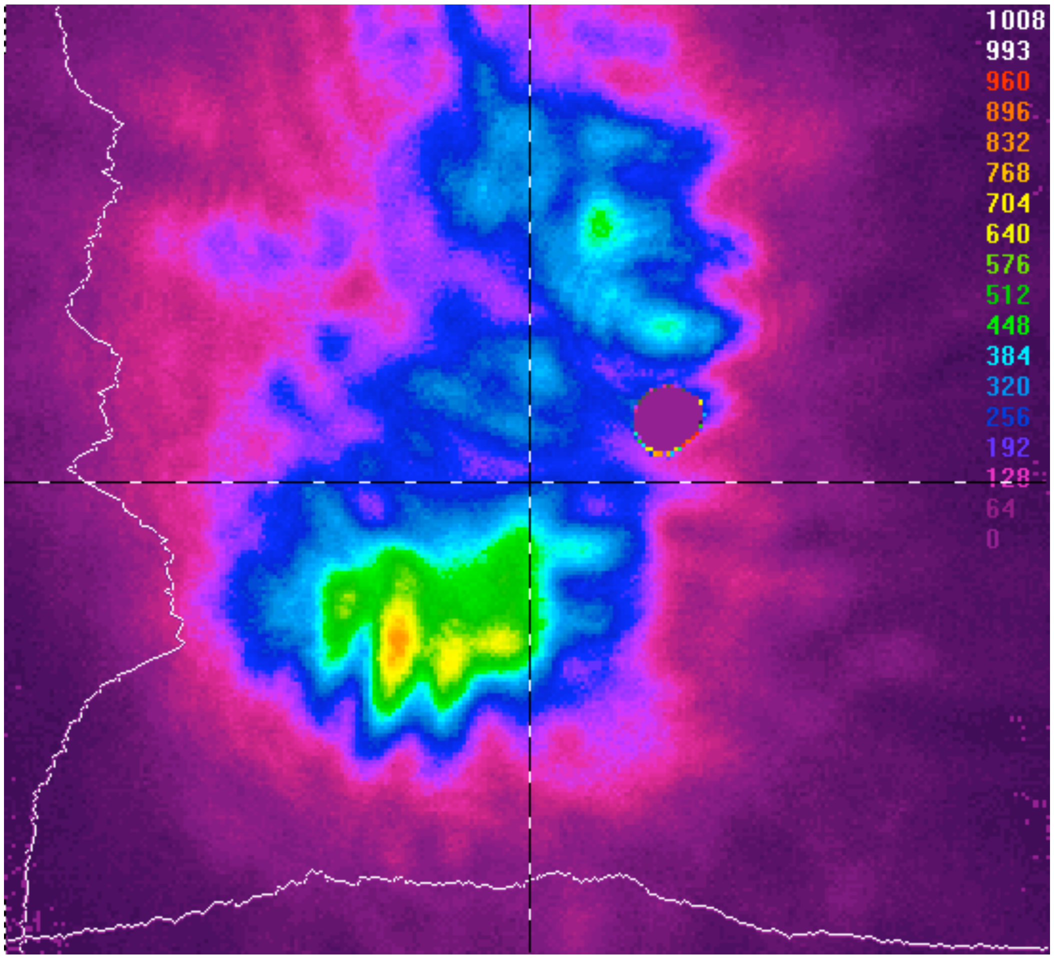
Au 10 μm on GHOST



Cu 10 μm on GHOST



Co 8 μm on GHOST



Areas for Improvement

- For cone targets, a backscattering diagnostic would greatly improve alignment.
- Better filters and/or beamsplitters would allow us to actually get ω and 2ω at the same time.
- A sidescattering diagnostic on the GHOST laser would greatly reduce alignment time.

References

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