Relativistic Apodization Through Ultrathin Liquid Crystal Films Using Gaussian and Laguerre-Gaussian Light

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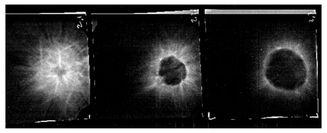
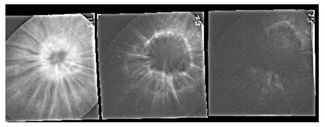
Orbital Angular Momentum

- Laguerre-Gaussian (LG) light contains Orbital Angular Momentum (OAM) and E- and B-fields not in Gaussian light
- *Macro*-scopic differences seen in OAM light (*extrinsic AM*) vs circular polarized light (*intrinsic AM*)
- Light primarily interacts with electrons in ultra-high intense laser plasma interactions as the ions are too heavy
- Experiments show a reduction in ion divergence angle in TNSA regime



OAM 1 um



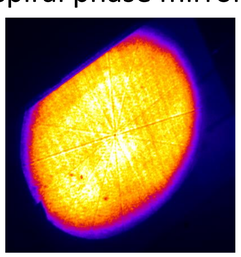
Gaussian 1 um

Relativistic Induced Transparency

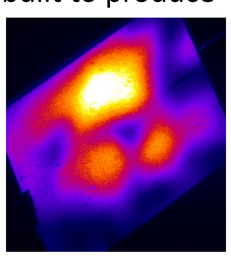
- Relativistic Induced Transparency (RIT) occurs when an opaque overdense plasma has the *effective* electron density drop by Lorentz factor, γ, as electrons become relativistic
- Transparency occurs when the *effective* electron density drops below critical density
- Recent experiments and simulations showed changes to polarization and ellipticity of linearly polarized light
- Their models suggest an anisotropy in the relativistic electron distribution driven by polarization direction

Experimental Setup at the Scarlet Laser Facility

- ***Goal:*** Measure the amount of transmission through ultrathin (<40 nm) liquid crystal (LC) targets using light with and without OAM
- Performed at Scarlet with 5J, 30 fs
- OAM light generated by reflecting fully compressed pulse off a 16-step spiral phase mirror built to produce light with l=1
- Transmission measured from light scatter off spectralon sheet



No Target Transmission



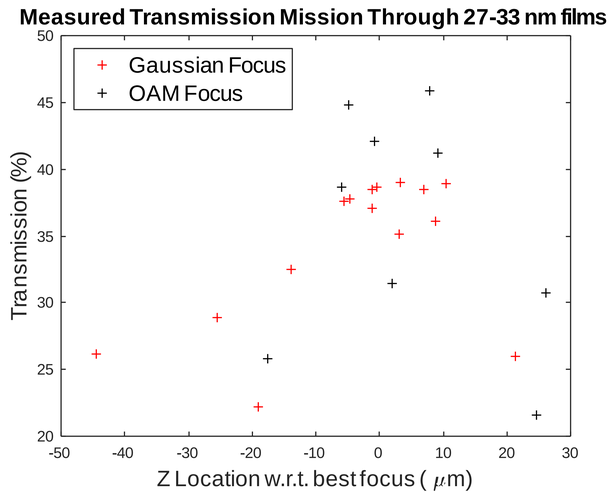
26 nm Target Transmission

Primary Results

- Measured Relativistic Transmission as function of spatial profile and distance from focus with ultrathin targets
- Transmission with Gaussian profile 25% lower than LG transmission though peak intensity was 35% higher
- Developed novel approach to calculate transmission using 2D spatial profile
- Developed novel wavefront measurement technique capable of measuring amount of OAM

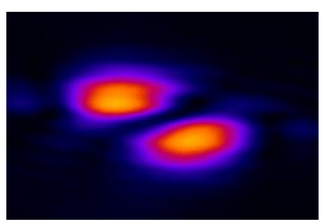
Results

- Max OAM transmission = ~45%
  - Peak OAM intensity = 4.2x10^{20} W/cm^2
- Max Gaussian transmission = ~35%
  - Peak Gaussian intensity = 5.7x10^{20} W/cm^2
- Saw *higher* transmission with OAM light even with *lower* peak intensity

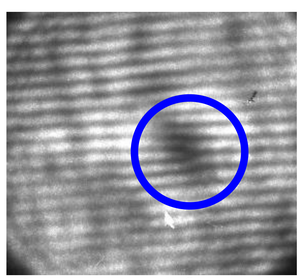


OAM Mode Quality and Measurements

- Measured OAM using three different techniques: Cylindrical lens (quantitative), Sagnac interferometer (qualitative), Phase-Diversity Phase-Retrieval (PD-PR)



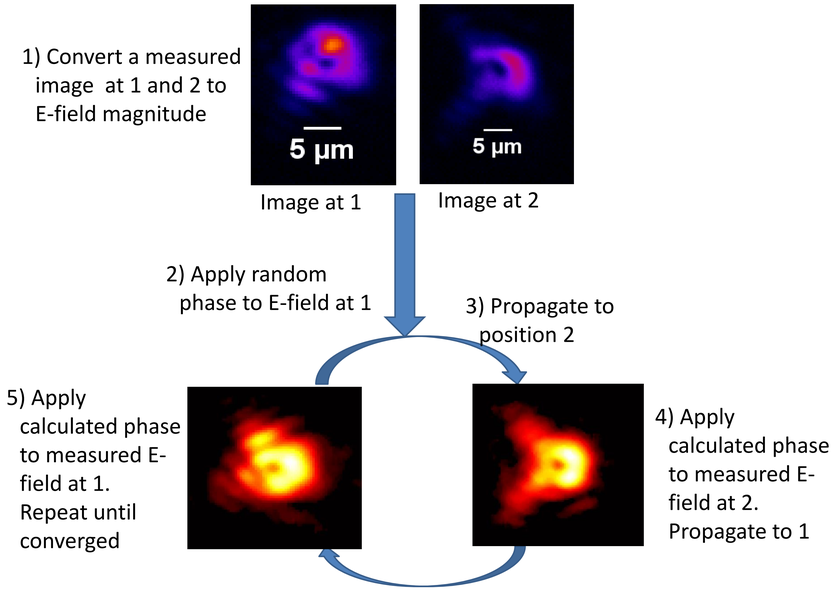
Cylindrical Focus ($l_{measured}$ =1.07)



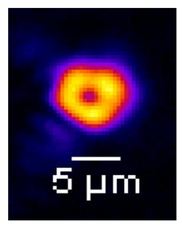
Sagnac Interference

Phase-Diversity Phase-Retrieval

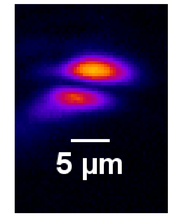
- Many conventional wavefront sensors can't solve OAM phase discontinuity
- Estimated wavefront from multiple images separated in Z



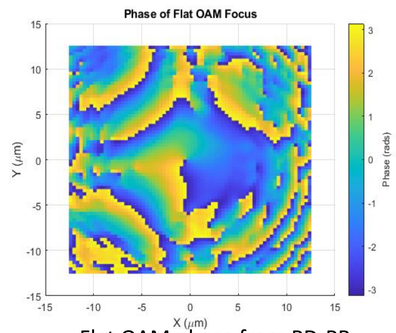
- Works with flat and astigmatic foci



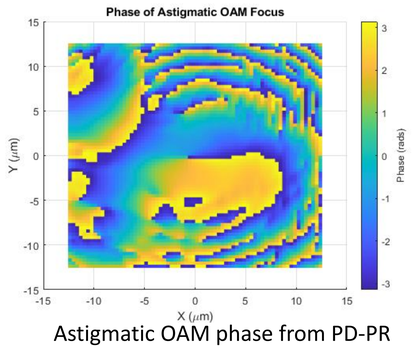
Flat OAM focus



Astigmatic OAM focus



Flat OAM phase from PD-PR (calculated $l = 0.97$)



Astigmatic OAM phase from PD-PR (calculated $l = 0.98$)

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