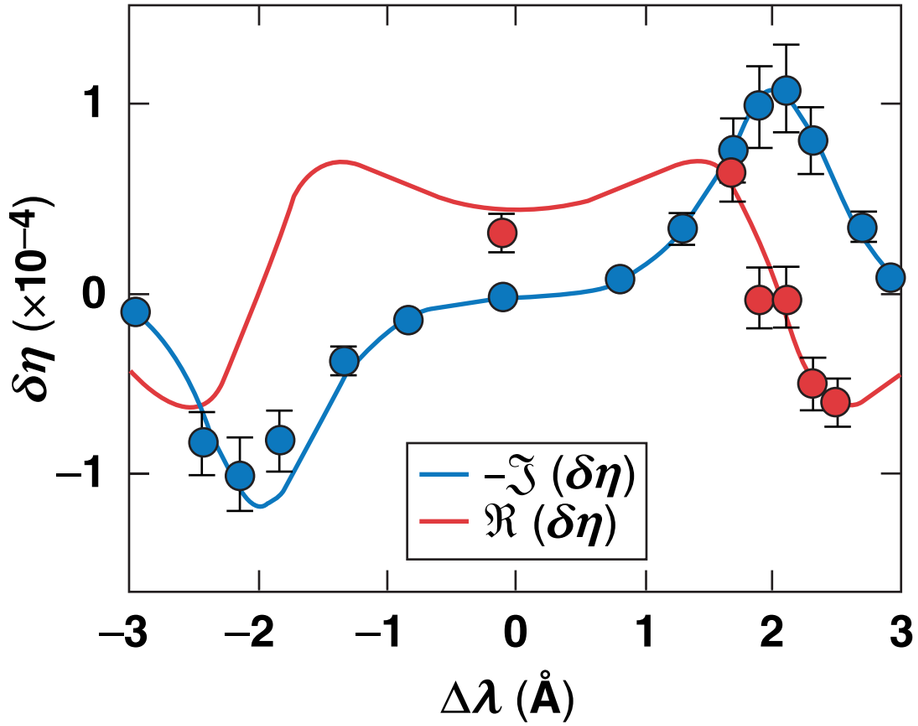
Measuring the Refractive Index of a Laser-Plasma System



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Summary

Recent experiments have validated the linear cross-beam energy transfer (CBET) theory and used it to demonstrate plasma photonic devices

- Linear coupled-wave theory is used to calculate CBET in direct- and indirect-drive inertial confinement fusion (ICF), but historically has not agreed with experimental data
- The theory was revisited recently with the proposal for laser-plasma photonic devices (wave plates and polarizers)*
- A recent experiment has found good agreement with the linear CBET theory and demonstrated an ultrafast, high-power, tunable laser-plasma polarizer**

*P. Michel *et al.*, Phys. Rev. Lett. 113, 205001 (2014).
**D. Turnbull *et al.*, Phys. Rev. Lett. 116, 205001 (2016).

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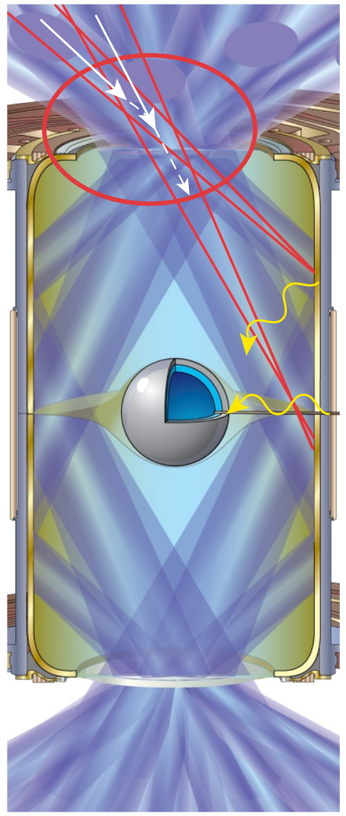
Collaborators

P. Michel, C. Goyon, B. B. Pollock, G. E. Kemp, T. Chapman, D. Mariscal, L. Divol, J. S. Ross, S. Patankar, and J. D. Moody

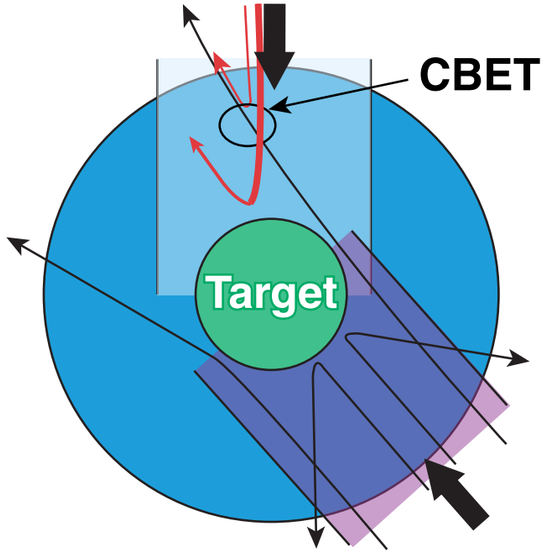
Lawrence Livermore National Laboratory
National Ignition Facility

CBET affects energy coupling and implosion symmetry in direct-drive and indirect-drive ICF

Indirect drive



Direct drive



Validating CBET models is an important component of simulating ICF implosions.

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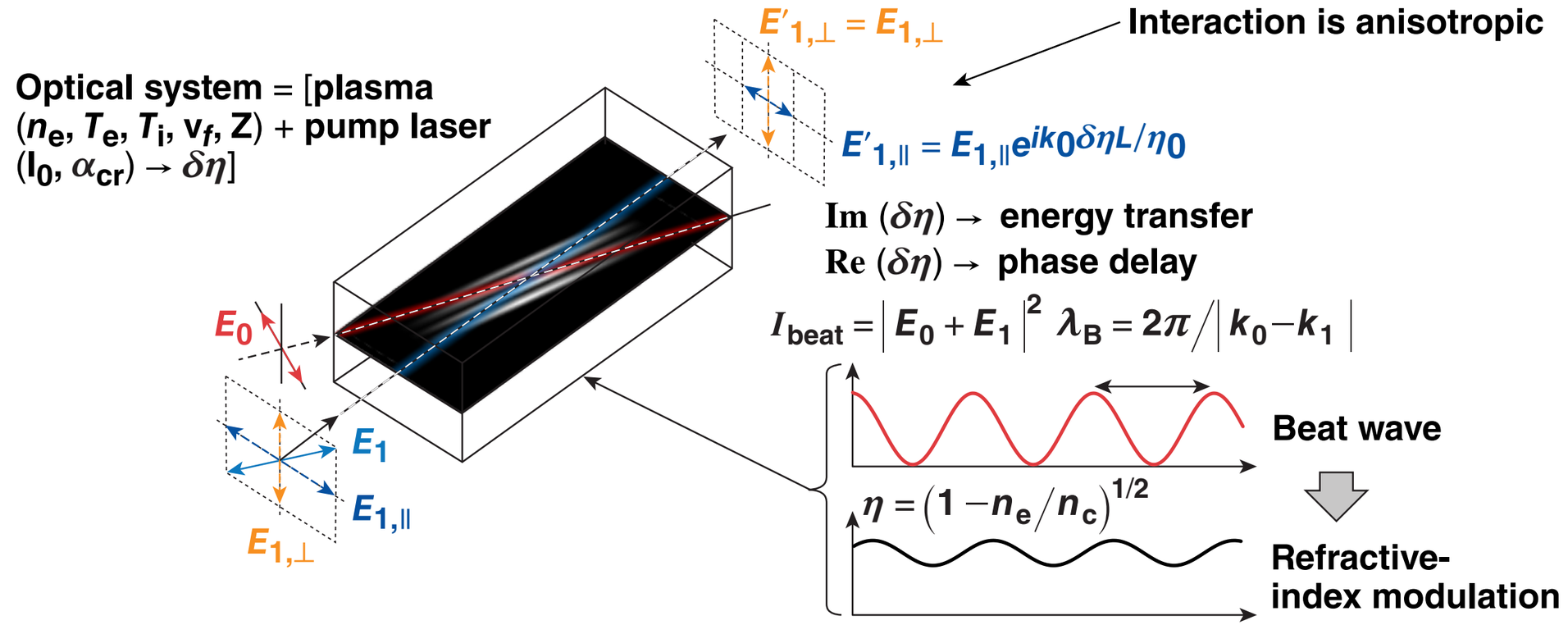
CBET theory* can be formulated as a laser-plasma system with a complex refractive-index perturbation operating on a probe beam



Such a system can modify the amplitude and/or polarization of the probe beam.

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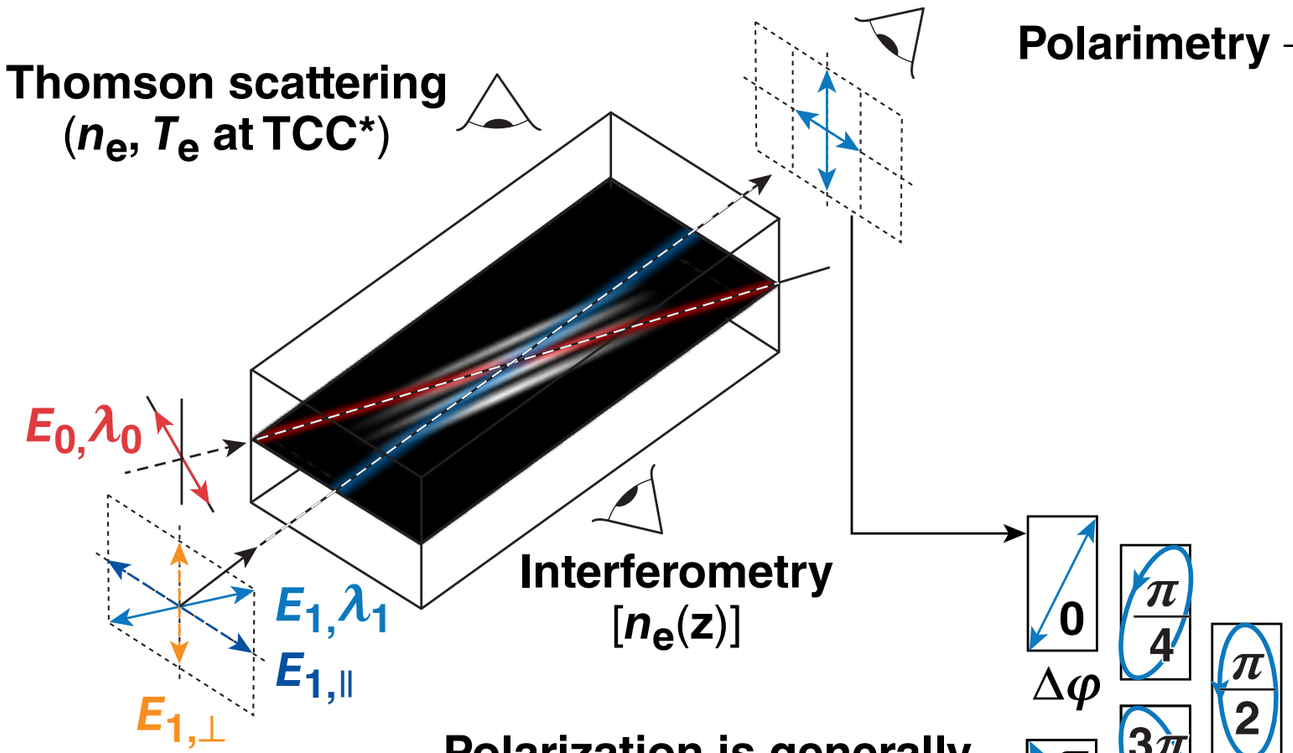
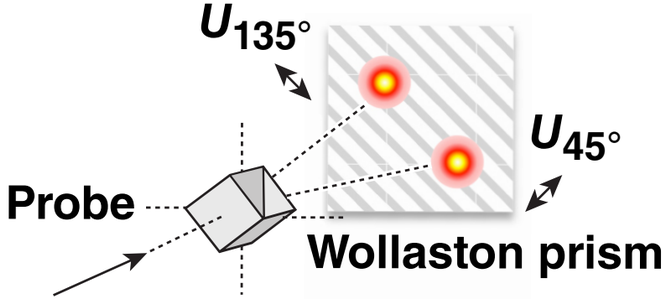
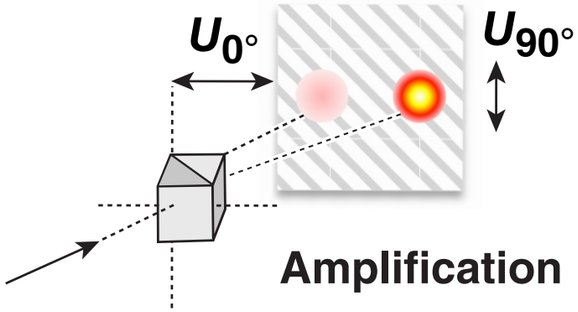
A pump-probe experiment with wavelength tuning was carried out to measure $\delta\eta$ as a function of $\Delta\lambda$



Polarization is generally elliptical because of induced phase delay

Polarimetry





Amplification

$$G_I = \ln\left(U_{0°}/U_{90°}\right)$$

Phase delay

$$\Delta\varphi = \cos^{-1}\left(\frac{\left[U_{45°} - U_{135°}\right]/\left[U_{45°} + U_{135°}\right]}{2\sqrt{U_{0°}U_{90°}}/U_{0°} + U_{90°}}\right)$$

*TCC: target chamber center

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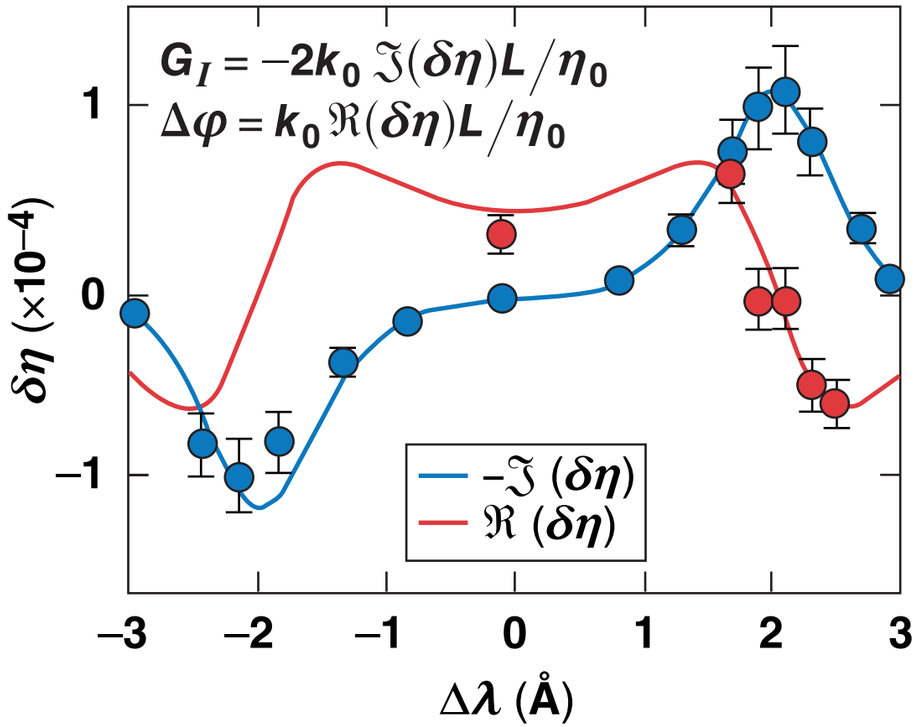
$\delta\eta$ is in good agreement with linear theory using inputs from measurements and *HYDRA*



Parameter	Theory input	Measured value	*HYDRA* simulation
n_e/n_c	0.0104	0.011±0.001	~0.009
T_e(eV)	220	224±24	~231
T_i/T_e	0.1200	—	~0.090
$\overline{\lvert v_{flow}\rvert}$(m/s)	~1.4 ×10^4	—	~1.4 ×10^4
I_0	~2.9 ×10^{13}	~3.6 ×10^{13}*	~3.6 ×10^{13}
$\bar{Z}$	3	—	2

This is the first time that the gain curve is resolved this accurately, and found to be in good agreement with linear theory; the first measurement of $\Re\,(\delta\eta)$ versus $\Delta\lambda$.

*Measurement did not include transport optic losses, IB absorption, or the possibility of nonideal pump spot.

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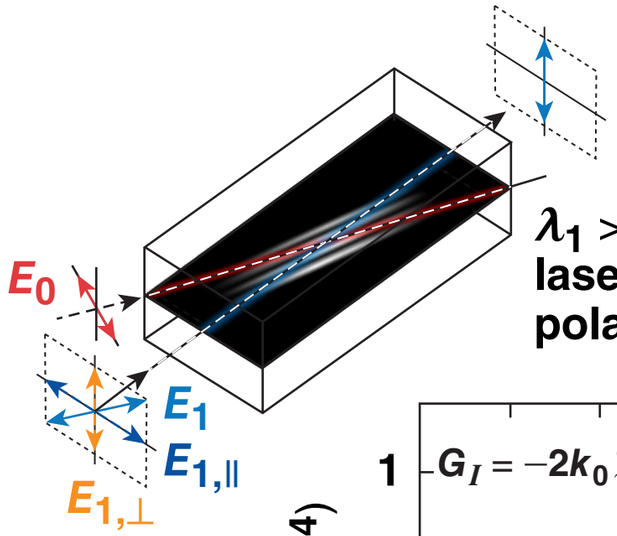
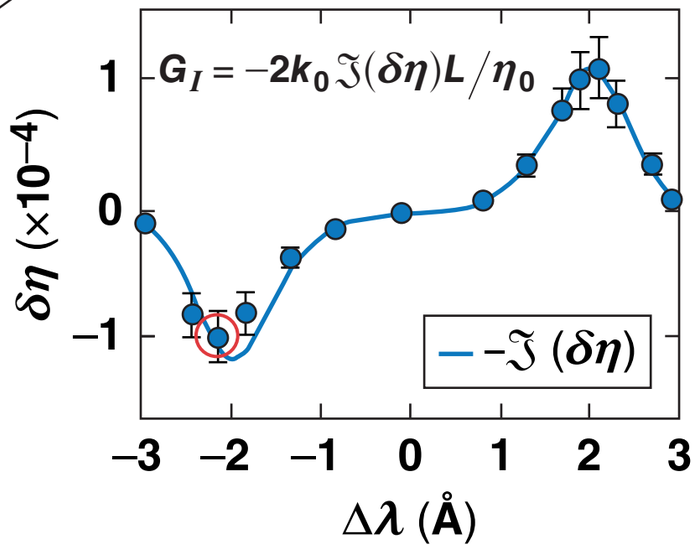
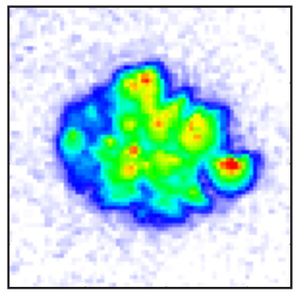
The system can act as a "plasma polarizer" with 85% to 87% extinction for these laser and plasma parameters



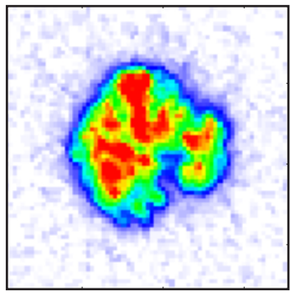
$\lambda_1 > \lambda_0$: laser-plasma polarizer



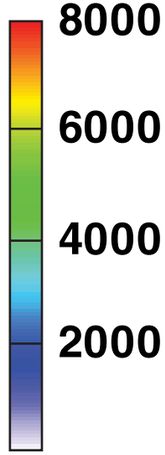
Vertical (preshot)



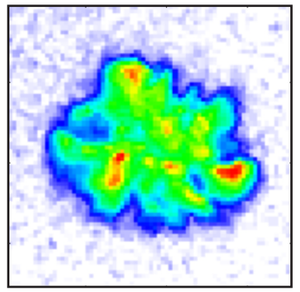
Horizontal (preshot)



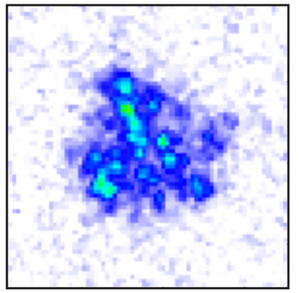
Counts



Vertical (shot)



Horizontal (shot)



~85% to 87% extinction

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D. Turnbull *et al.*, "Measuring the Refractive Index of a Laser-Plasma Optical System," submitted to Physical Review Letters.

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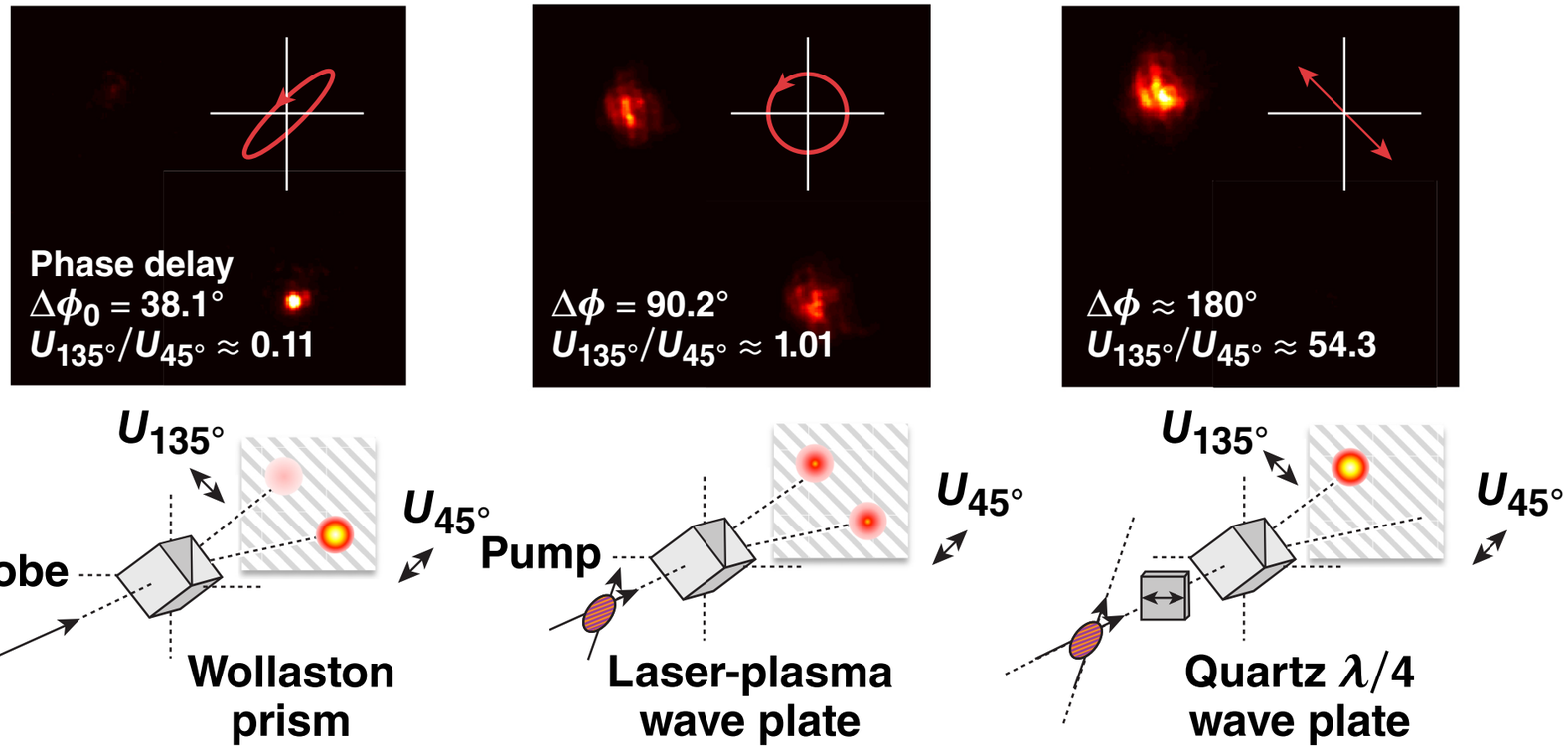
The elliptical probe was converted to a nearly ideal circularly polarized beam by inducing a 52° phase delay in plasma



This is the first demonstration of a near-ideal tunable laser-plasma wave plate.

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