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Diagnosing the onset of relativistically induced transparency in high-energy laser-driven proton acceleration experiments

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Ion acceleration via compact laser-plasma sources holds great potential for applications from radiation therapy research to fusion research. Achieving the desired beam quality requires a deep understanding and precise control of laser-plasma interactions. Our collaborative research at the DRACO PW (HZDR) and J-KAREN-P (KPSI) laser systems investigates the promising regime of Relativistically Induced Transparency (RIT).
Previous studies [1] achieved high-performance proton beams (>60 MeV) in an expanded foil configuration, identifying an optimum at target transparency onset. Later experiments recorded proton energies over 100 MeV [2], emphasizing transparency onset timing in optimizing beam parameters. Using particle and laser diagnostics, we explore the correlation between transparency onset and acceleration performance.
This contribution details our recent investigations into spectral components of transmission and emission from laser-plasma interactions. Building on established methodologies [3], we apply spectral interferometry, using the unperturbed laser beam as a reference, and correlate findings with proton acceleration. Our results suggest a promising direction for analyzing spectral and spatial distribution, offering deeper insights into laser-plasma interactions and optimizing beam quality parameters.

[1] Dover, N.P. et al.: Light Sci. Appl. (2023).
[2] Ziegler, T. et al.: Nat. Phys. (2024).
[3] Williamson, S.D.R. et al.: Phys. Rev. Appl. (2020).

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