Developing in-situ Intensity Diagnostics for High Energy Density Physics Experiments

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Abstract: Our goal is to provide reliable single shot measurements of the peak intensity of ultra-intense laser fields. The peak intensity of laser pulses is a crucial parameter in short-pulsed laser-based HEDP experiments. Generally peak intensity is inferred from energy, focal spot diameter and pulse duration measurements using heavily attenuated pulses not fully amplified, which may differ tremendously from the experimental pulses. Our approach is a two-prong effort utilizing ionization rates in ultra-intense laser experiments. On one side, we study the ultra-intense ionization of deeply bound noble gas ions, for which the intensity dependent ionization rate is not known. On the other side, we are using our knowledge of ionization to make a single-shot peak intensity measurement inferred from ionization of multi-species gas mixture.

In-situ Calibration Methods

Measuring intensity dependent reaction products
Creation of ion species
Exiting electron energy
Bremsstrahlung/radiation cutoff

Intensity calibration obtained by matching experimental ionization yields of Ne" (circle) and He" (filled square) with calculated ion yields from ADK model (solid line for Ne" and dashed line for He"). Both Ne" and Ne" data were simultaneously collected from a gas mixture of Ne-Ne.

Ultra-Continuum Dynamics

Exiting momentum distribution of electrons ionized from 10^11 ions

Photoelectron Spectroscopy

Electron TOF tube

Nuts and Bolts: What we need
Modular chamber

Typical multi-detector UV/VIS chamber

High Field Continuum Paradigm

WKB/ADK Approximations

In-situ calibration obtained by matching experimental ionization yields of Ne" (circle) and He" (filled square) with calculated ion yields from ADK model (solid line for Ne" and dashed line for He"). Both Ne" and Ne" data were simultaneously collected from a gas mixture of Ne-Ne.

Fancy Wave Function Picture

NSE solution to ionization
\text{Ar}(1s^22s^2) + 10^{19}\text{W/cm}^2 \rightarrow \text{Ar}(1s)^{10}

Important of Intensity Calibration

Helium ionization known for 10^{18} \text{W/cm}^2 at the focus error estimate ± 60% intensity ± 25% in E-field

Experimental pulse characteristics may differ drastically from calculated idealistic values

Typical solid target-laser interaction

Experimental Ion Spectrum

A^+ to A^{10+} yields measured for rates from 10^{19}/s to 10^{23+/s}, saturation for 25 fs pulse

Experiment vs. Single Electron Rates

10^6 laser shots per point
Intensity calibration with He-Ne mixture

Experimental Results

Theory vs. Experiment Touchstone

Very good agreement within the experimental uncertainty in intensity of 2 ± 10^{11}\text{W/cm}^2

References: