

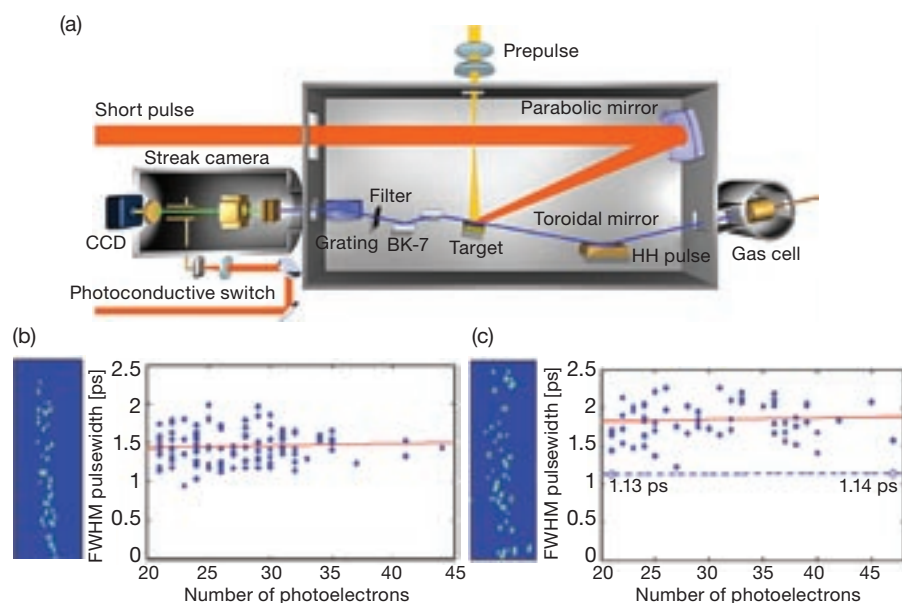
Picosecond Soft X-Ray Laser Pulses from an Injection-Seeded Plasma Amplifier

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Compact soft X-ray laser (SXRL) plasma amplifiers have been used to generate intense pulses ranging from 5 picoseconds to nanosecond duration, governed by the duration of the gain. The recent demonstration of injection-seeded SXRL¹⁻³ creates a fundamentally new regime for generating short SXRL pulses in which the pulsewidth is governed by the amplifier bandwidth and is independent of gain duration. In a recent experiment, we measured the duration of phase-coherent SXRL pulses from an injection-seeded plasma amplifier created by irradiating a solid target. The result shows a pulse from an SXRL plasma amplifier of approximately 1.1 ps.

We used an ultrafast streak camera⁴ to make single-shot measurements of soft X-ray pulses generated by seeding the 32.6 nm line of Ne-like Ti with the 25th harmonic of a Ti:sapphire laser.⁵ The SXRL amplifier plasma was created by laser-heating a Ti slab with pulses from a table-top Ti:sapphire laser system. We seeded the plasma amplifier with pulses from the 25th harmonic generated by focusing 20-mJ pulses from the same laser into an argon gas cell. The seed pulses exiting the gas cell were relay-imaged onto the input of the plasma amplifier using a toroidal mirror. The streak camera was synchronized with the amplifier gain using a photoconductive switch.

We determined the temporal resolution of the streak camera *in situ* by measuring the pulse duration of the high harmonic (HH) seed pulse, whose pulse duration of roughly 50 fs is much shorter than the camera resolution. As shown in the figure, we plotted the measured pulsewidth, which is in effect the camera resolution, as a function of the number of detected photoelectrons. Here, pulsewidth is defined as the time interval containing 76 percent of the electrons.



(a) Set-up used for measuring pulse duration of an injection-seeded soft X-ray laser. (b) HH single-shot streak and measured pulse width as a function of the number of detected photoelectrons. (c) Measured pulse duration of the amplified seed pulse. Dashed line is deconvoluted pulse width.

In the streak camera measurement of the amplified seed pulses, the pulse width of the seeded laser, $T_p = 1.13 \pm 0.47$ ps, was obtained by deconvolution using

$$T_p = \sqrt{T_m^2 - T_{HH}^2}$$

where T_m and T_{HH} are the measured seeded laser pulsewidth and the streak camera resolution, respectively.

The measured pulse width is in good agreement with simulations performed using a 3-D propagation code that self-consistently computes the amplification of the seed pulse in a fully transient approach considering gain saturation. Simulations suggest that SXRL pulse durations of a few hundred femtoseconds should be achieved by seeding a higher density plasma amplifier in which collisional broadening increases gain bandwidth. For example, gain-saturated laser pulses of about 290 fs duration could be obtained

by seeding a 3.5-mm-long 10.9-nm Ni-like Te plasma amplifier with an electron density of $2 \times 10^{21} \text{ cm}^{-3}$. Δ

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