The need for bright, energetic ultrafast X-ray laser pulses has motivated the commissioning of X-ray free electron lasers. Alternatively, plasma-based X-ray lasers allow many experiments requiring bright, high energy, X-ray laser pulses such as single-shot nano-scale imaging to be conducted in compact facilities. These lasers provide extremely monochromatic radiation, typically $\Delta \lambda / \lambda = 3 \times 10^{-5}$, and when injection-seeded can reach full spatial and temporal coherence. However, compact repetitively fired gain-saturated X-ray lasers have been limited to wavelengths above $\lambda=8.85$ nm [1].

We have now extended compact plasma-based X-ray lasers to $\lambda = 6.85$ nm by transient traveling wave excitation of Ni-like Gd ions in a dense plasma [2]. The X-ray lasers were excited irradiating solid slab targets with a sequence of two laser pulses from a $\lambda=800$ nm chirped pulse amplification Titanium:Sapphire laser. The first pulse ionizes the plasma to the vicinity of the Ni-like ionization stage, is followed by a sub-picosecond pump pulse impinging at grazing incidence that rapidly heats the electrons to produce a transient population inversion by collisional electron impact excitation. Isoelectronic scaling also produced strong lasing at 6.67 nm and 6.11 nm in Ni-like Tb, and amplification at 6.41 nm and 5.85 nm in Ni-like Dy. This scaling to shorter wavelengths was obtained progressively increasing the pump pulse grazing incidence angle to access increased plasma densities. We experimentally demonstrate that the optimum grazing incidence angle increases linearly with atomic number from 17 degrees for Z=42 (Mo) to 43 degrees for Z=66 (Dy). The results will enable applications of sub-7 nm lasers at compact facilities.

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