Optimum Time Configuration of Pump Pulses for X-ray Plasma Lasing

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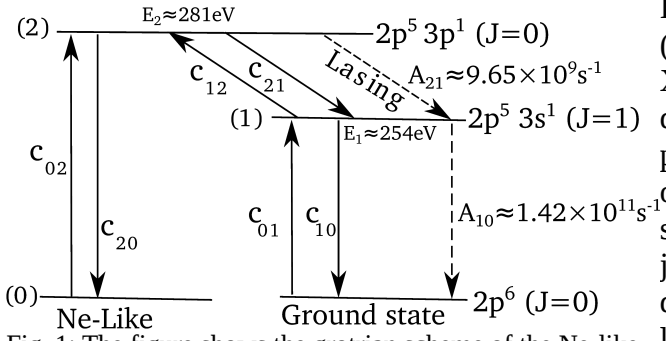

Fig. 1: The figure shows the grotrian scheme of the Ne-like Argon. The energy levels schematically are composed of the upper (2) and lower (1) lasing states and the ground (0) state.

In the transient collisional excitation (TCE) scheme for the plasma-driven X-ray laser, it is critical to optimize the duration and time delay between pump-pulses. All of so far reported optimization comes from experimental studies which had a lack of theoretical justification. This could explain differences between the results of different laboratories.

In this study, we have done parametric simulations in order to systematically investigate optimum time configuration of pump pulses. In the plasma-driven X-ray lasers, gas targets have several advantages over solid targets, such as the soft density gradients, being free of debris, high repetition rate, long unbroken operation [1]. Hence, our simulations were done on the soft X-ray lasing across a Ne-like Argon (Ar^{+8}) at wavelength λ=46.9nm in the $2p^5\ 3p^1(J=0) \longrightarrow 2p^5\ 3s^1(J=1)$ laser transition (see Figure. 1).

We studied parametrically the effect of the pulse duration on the electron temperature or density for lasing. It is demonstrated that the optimum time scale required to achieve Ne-like ions (as a ground state) as well as the time required to generate a population inversion depends on the combined effect of the temperature and density. For $T_e \geqslant 100$eV, the ratio of the pumping-time for the population inversion to the relaxation time from the upper level can be as high as a factor of 100, depending on the electron density. Dielectronic recombination has a stronger effect on the ionization time of Argon to have Ar^{+8} at temperatures $T_e \lesssim 50$eV.

Further, using pico-second pulses (which produce higher electron density and temperatures), the time it takes for the creation of Ne-like ions (t_{ion}) will be close to the relaxation time from the upper level (t_{rel}) and the time for pumping of the population inversion (t_{pum}). In order to maximize the total X-ray laser emission from the plasma, the total number of X-ray emitters should be maximized at one specific time. This can happen with the pumping time for the population inversion being close to the relaxation time from the upper level.

It is concluded that in the case of one pulse driven on the target the highest gain can be achieved using a pulse duration in the range of 10-30ps. In the case of one long pulse as a pre-pulse and one short pulse as a main pulse, a higher gain can be achieved by overlapping a short pulse and a long one. In the case of two short pulses (1ps) one short pulse as a pre-pulse and one short pulse as a main pulse, a higher gain can be achieved with a time delay of the order of 40 ps.

[1] M. Davidkova, et. al., *Journal of Radiation Research*, **168** (3), 382, (2007).