Sum-frequency generation of extreme-UV light

According to the advance of high-power laser technology, ultra-short coherent extreme-ultraviolet (EUV) and soft x-ray sources can be driven directly from the laser-plasma interaction, such as EUV/soft x-ray lasers and high-harmonic generation. Therefore, the nonlinear wave-mixing process now is possible to be extended to such short wavelengths. In this presentation, we propose that rare gas ions are proper interacting medium. For example, if the argon atom is ionized to be Ar^{3+} ion, the ionization potential of the forth electron is 59.81 eV. Then the EUV photons with photon energy less than 59.81 eV (wavelength > 20.7 nm) will not be absorbed, as a result of that photoionization cannot occur. However, the residual electrons can still provide the nonlinear response for nonlinear wave-mixing. By using Cowan's atomic structure code, we calculate the dipole matrix elements of the Ar^{3+} ions, and then its third-order nonlinear polarizability for sum-frequency generation of two IR photons (800 nm) and one EUV photons (45 nm). The result is about 3.16×10^{-63} (coul-m^4/$volt^3$). After that, we propose an experimental setup incorporated with one 40-mJ, 30-fs IR pulse, one 1-μJ, 20-fs EUV pulse, and an Ar gas jet with 10^{17} cm^{-3} density. The calculation shows that the energy of the sum-frequency generation output can reach 1 nJ, corresponds to 0.1% conversion efficiency relative to the incident EUV pulse energy. This is a promising method for the manipulation of EUV waves.