Enhanced Spectrum Broadening of Ultrashort Laser Pulses by Mixing Krypton and Nitrogen Gases

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Abstract: Enhanced spectrum broadening of ultrashort laser pulses is investigated within a hollow core waveguide filled with a mixture of krypton and nitrogen gases. Nitrogen gas is injected at the front end of the waveguide, while krypton gas is introduced at the back, resulting in efficient extension of the spectrum broadening towards shorter wavelengths while maintaining the longer wavelength range.

Noble gases are widely used in pulse compression, supercontinuum generation and high harmonic generation (HHG) experiments [1-3]. These atomic gases only have an instantaneous part of nonlinear refractive index. In these experiments, the ionization of noble gases induces a strong spectrum blue-shift. To maintain the red wavelength segment, a mixture of noble gas and nitrogen gas can be employed. For molecular gases like this, Raman response must be considered. The continuous spectral red-shift was induced by simulated Raman scattering over a long propagation distance in nitrogen filled hollow core fibers [4]. Molecular gases can also be used for supercontinuum generation [5, 6] and self-compression [7]. A mixture of krypton and oxygen gases can be used to obtain the uniform spectral broadening in both the red and blue wings [8].

In this study, an experiment was conducted to facilitate spectral broadening by using krypton (Kr) and nitrogen (N_2) gas to fill a hollow core waveguide. There are two inlet holes on the hollow core waveguide, in which, gas can be configured to enter either of the holes (front or back), illustrated in Fig. 1. Thereafter, Fig. 2(a) & (b) show the spectra after the waveguide was filled with only Kr and N_2 gas, respectively. The input spectra is represented by the blue curve, and the orange curve for results with respective gases. Fig. 2(c) & (d) show the resultant spectra after the waveguide, after mixing Kr and N_2 gas in two alternating configurations – with either gas input via the front/back inlet. Spectral broadening was found to be more efficient with N_2 gas input from the front, and Kr gas from the back, Fig. 2(c) – compared to the alternate configuration, Fig. 2(d).

These results indicate that the spectrum can be broadened from the addition of the molecular gas, N_2. Importantly, the N_2 gas is to be filled at the front inlet, before the Kr gas, as nitrogen has a higher ionization energy than that of krypton. If Kr gas is filled in front, it will ionize earlier and decrease the laser intensity due to plasma-defocusing and ionization loss. This leads to a less broadened spectrum as shown in Fig. 2(d). This finding benefits self-compression in hollow core waveguide to generate shorter pulses [9].

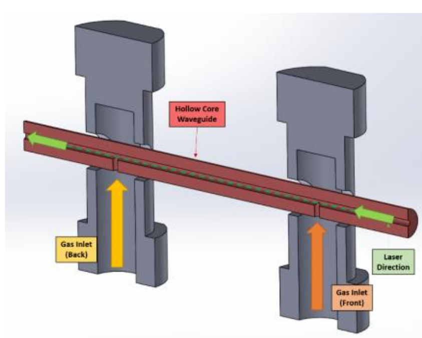

Fig. 1. Cross section illustration of hollow core waveguide and inlets for gas.

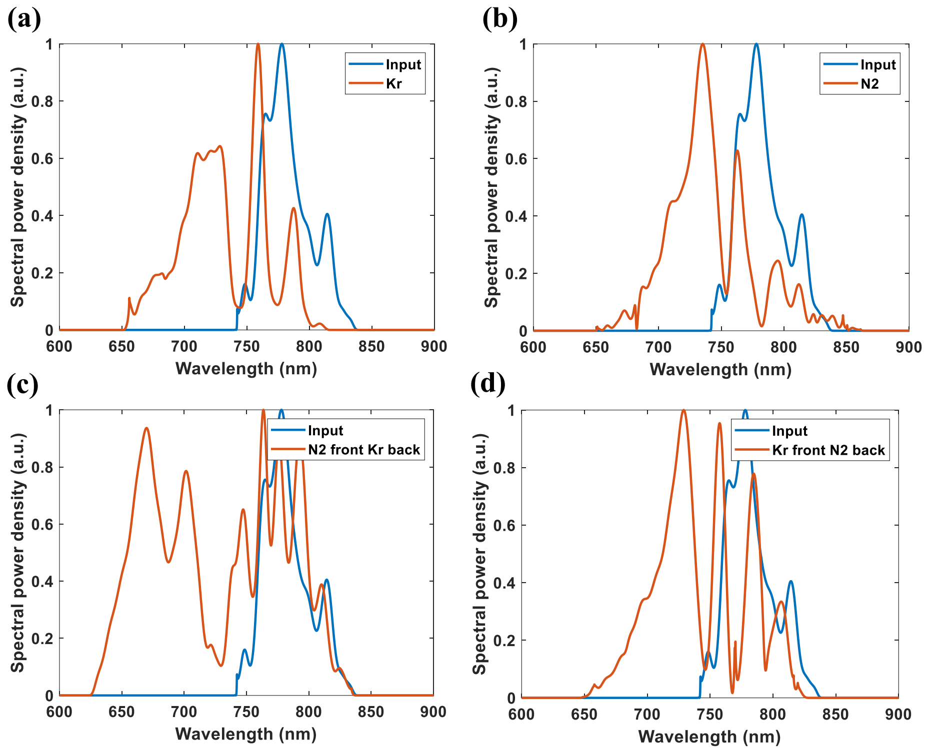

Fig 2. (a) Resultant spectra with only Kr gas input. (b) Resultant spectra with only Nitrogen gas input. (c) & (d) Resultant spectra with alternating configurations of Kr and nitrogen gas input.

Funding

This research is supported by A*STAR (C222812005).

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