SUPPRESSION OF FILAMENTATION BY PHOTONIC CRYSTALS

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Nonlinear propagation of intense ultrashort laser pulses in transparent materials produces a unique and spectacular phenomenon termed femtosecond filamentation. This leads to a transformation of an ultrashort-pulsed laser beam into a light filament, which possesses an ultra-broadband spectrum, termed supercontinuum. Here we propose and substantialize an alternative idea that photonic crystals can efficiently suppress the emerging filamentation. It is well known that photonic crystals can affect the overall diffraction of the beam. For example, the reduced or increased spatial dispersion curvature corresponds to weakened or strengthened diffraction. Another possibility is obtaining a spatial dispersion curve with a negative curvature corresponding to anti-diffraction. Considering this, we can infer that it is possible to devise a photonic crystal with such a geometry, that results in a spatial dispersion regime that can compensate for the nonlinear Kerr focusing of the beam, thus effectively suppressing filamentation. Numerical simulations were performed using a forward beam propagation method, which approximates the envelope of the beam propagating in a slowly varying medium. The profile of refractive index modulation is chosen to be harmonic in both the transverse X and the longitudinal Z directions. The periodicities in both directions were varied to determine an optimal geometry, with the longitudinal period being tied to the transverse period through the Talbot length. It is convenient to introduce the geometric constant Q which is the inverse of the longitudinal period normalized to the Talbot length. In the general case, for a photonic crystal with constant period and for all values of the geometric constant Q that are close to 1, there are multiple dispersion curves corresponding to different Bloch mode branches. This is often undesirable since it makes it impossible to precisely control the diffraction of the beam, however this issue can be overcome by introducing an adiabatic chirp to the longitudinal period of the photonic crystal. We do this by starting at a longitudinal period corresponding to a geometric constant Q sufficiently far from 1 and slowly approaching the desired Q. From the beam diameter evolutions, we can see that in the homogeneous case the beam diameter first increases, but eventually the beam starts to converge and collapses. Using those same beam parameters but this time in a photonic crystal we can see that the beam diameter again initially increases, however this time the beam does collapse, instead the beam converges only a little and the beam diameter asymptotically approaches some value for which the diffraction and nonlinear focusing are balanced. The results show that using a photonic crystal with a geometry characterized by a value of Q close to 1 gives the desired result. In addition, using positive and negative chirp, both increased diffraction ($Q > 1$) and anti-diffraction ($Q < 1$) can be achieved.