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PREPRINT

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This paper was prepared for submittal to the
IEEE/Lasers and Electro-Optics Society
Optical Society of America
August 28 - September 2, 1994
Amsterdam, The Netherlands

June 1994

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High Power Spectral and Spatial Beam Control Using Self-Phase Modulation and a Multisegment Monochromator

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Abstract

We present a novel optical system for forming high power beams with spatial separation of selected spectral components. Self-phase modulation in an optical fiber creates multiple wavelengths. A segmented diffraction grating device provides spectral control.

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*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

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To suppress stimulated Brillouin scattering (SBS) in fusion plasmas, a four-beam, four wavelength illumination scheme is being proposed for the next-generation fusion laser being designed at Livermore. We are simulating this geometry on the Nova laser, to support target experiments intended to observe SBS effects. A novel optical system splits one of Nova's ten beams into four segments, with each segment containing one wavelength.

We generate multiple wavelengths with two Q-switched, single longitudinal mode Nd:YLF lasers tuned 4.4 Angstroms apart using intracavity etalons. The pulsed beams are made to co-propagate in a 10m, single mode fiber, where they interfere at high intensity, producing many sidebands through self-phase modulation (Fig. 1). We have found theoretically and experimentally that the sideband amplitudes are less sensitive functions of oscillator power when modulation index is high. Therefore, a large number of sidebands is generated to improve stability. Light from the fiber is amplified and directed into the main amplifier arm.

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In the arm, four of these sidebands are selected to form a four-quadrant beam. An apodizer divides the multifrequency beam into four shaped segments, pre compensating for geometric distortions caused by diffraction gratings used near the Littrow angle (Fig. 2). An array of four diffraction gratings, each tilted at a slightly different angle, disperses the sidebands in each segment. Also, the gratings are tilted in a "V" configuration to reduce temporal delay across the beam. As the dispersed beam passes through a relay telescope, a focal plane slit removes all but one sideband from each segment. As the different segments each have a different angle imposed on the dispersed beams, what emerges from the telescope is four segments each with a different single wavelength (Fig. 3).

Any sideband can be assigned to any segment by tuning the gratings. We select every second sideband to maximize the wavelength separation between the segments. Limits are imposed on the maximum wavelength separation by gain narrowing and oscillator tunability. A Lyot filter and segmented absorption filters compensate for gain narrowing and other spectral effects to equalize the segment amplitudes at the arm output.

After amplification, the four-wavelength beam passes through a four-segment frequency doubler and tripler. Each segment of the tripler is independently tuned to the appropriate wavelength. At the tripler output, 750 joules of UV light in each wavelength is focused on target.

Figure captions.

Figure 1. The spectrum produced by self-phase modulation of two wavelengths in a single-mode fiber. The spacing of adjacent sidebands is 4.5 Angstroms.

Figure 2. Geometric distortion is caused by off-Littrow diffraction from an array of gratings. The angle between the incident and diffracted beams is six degrees.

Figure 3. A schematic diagram of the multisegment monochromator system in the amplifier arm. The four-segment beam is relayed throughout the rest of the amplification stages.

Figure 1

Figure 2

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