Intense coherent supercontinuum via IR pulse propagation in multiple thin plates

Daniel Thrasher [*], Chih-Hsuan Lu, Chia-Lun Tsai , Yi-Hsun Tseng , Ming-Chang Chen, Shang-Da Yang , A. H. Kung [*]

Institute of Photonics Technologies, National Tsing Hua University, Hsinchu, Taiwan
[*] Institute of Atomic and Molecular Sciences, Academica Sinica, Taipei, Taiwan
dthrasher@wisc.edu

Abstract: We report on the coherent supercontinuum produced by ultra-fast IR pulses propagating through thin plates. The -20 dB supercontinuum spans from 750 to 1650 nm and has a total energy of 100 uJ.

OCIS codes: 320.6629 supercontinuum generation, 320.7120 ultrafast technology

Multiple octave compressible supercontinuum have been successfully demonstrated through precise alignment of gas filled hallow core fibers [1] and cascaded optical parametric amplifiers (OPA) [2]. Both techniques suffer severely from beam pointing drift, require mJ pump pulses and/or expensive non-linear crystals. It has been shown that intense supercontinuum can be more simply achieved when pump pulses of 25 fs duration with a central wavelength of 800 nm propogate through a series of thin (about 100 μm) plates [3]. This multiple thin plate (MPContinuum) method allows for the nonlinear processes of self phase modulation, and self steepening to induce spectral broadening of the incident pulse before the formation of multiple filaments destroys the output spatial mode quality and/or leads to optical damage. Previous to the MPContinuum technique, compressible supercontinuum derived from nonlinear interactions in bulk materials were limited in pulse energy to only several μJ.

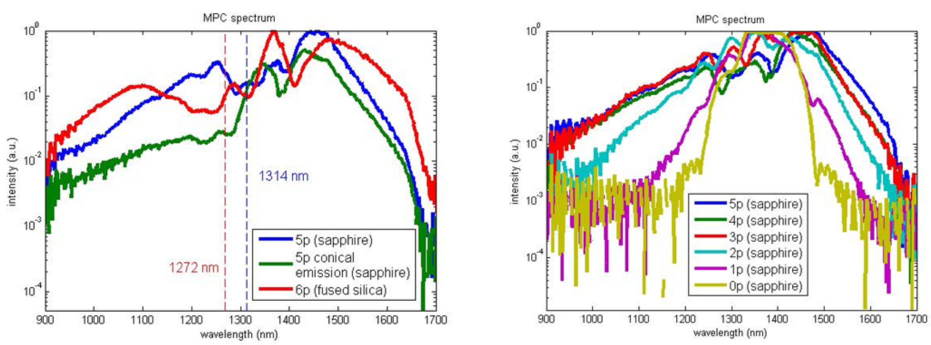

Fig. 1. Left: Spectral broadening from thin plates of fused silica, and sapphire. The off axis conical emission spectrum of sapphire is also included. The vertical dashed lines mark the zero GVD wavelength of the respective material. Right: spectral broadening as the number of thin sapphire plates is increased.

In this work, we extend the technique of MPContinuum by applying IR pump pulses (1.2 to 1.5 μm) at or near the zero group velocity dispersion (GVD) wavelength of several materials, including: fused silica, sapphire, and calcium fluoride. We report a near 100 μJ coherent supercontinuum spanning from 750 to 1650 nm at the -20 dB level in an all solid state system. The output has an excellent spaital mode quality and contains more than 50 percent of the incident pulse energy with simple alignment. The output spectrum of several thin plate materials is characterized in both normal and anamoulous GVD regimes. The coherence of the supercontinuum is also demonstrated, see for instance Fig. 2.

The pump pulse for this MPContinuum is the tunable signal output from a home built three stage OPA pumped with carrier envelope phase stabilized, 25 fs, 800 nm, 1.8 mJ pulses at a 1 kHz repitition rate. The OPA signal has 160 μJ per pulse at 1.35 μm and is 40 fs in duration. These pulses are focused into several thin plates of variable spacing and thickness.

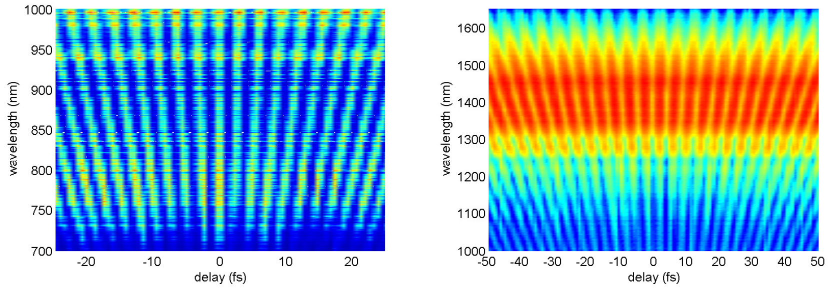

Fig. 2. Temporal coherence measurements. Two spectrometers are used to span the supercontinuum.

Typical spectral broadening of the IR pulse after 5 pieces of sapphire is shown in Fig. 3. As the number of plates is increased, self phase modulation and self steepening induce increasing spectral broadening. The prominant blue pedestal apparent after adding the final plate is a signature of self steepening.

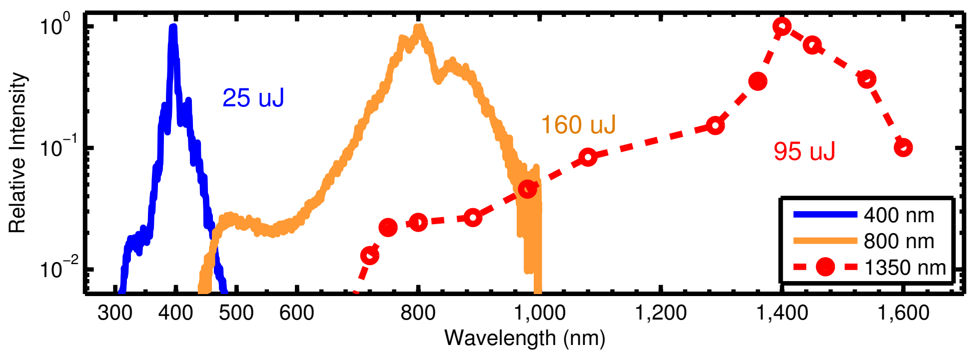

Fig. 3. Individually normalized MPContinuum from different pump wavelengths. The work presented in this paper is the red curve generated with one piece of 100 μm sapphire followed by 4 pieces of 200 μm sapphire. Because our commercial spectrometers have poor response around 1 μm, we measure the supercontinuum with a prism and pyro-electric power meter in order to confirm the -20 dB corners. The other supercontinuum shown are produced using 5 pieces of 100 μm fused silica. The integrated central lobe pulse energy for each MPContinuum is listed on the plot.

We have demonstrated a coherent supercontinuum spanning more than one octave with high efficiency and less than 1 mJ input power. It can be combined with other coherent MPContinuum to create an optical waveform synthesizer. When compressed and combined with other MPContinuum, the transform limited pulse duration is 1.2 fs. The simple alignment, reliable efficiency, and low cost of thin plate material enables the IR MPContinuum to make intense coherent supercontinuum more easily attainable by the ultrafast optics community.

References

1. A. Wirth, M. Th. Hassan, I. Grguras, J. Gagnon, A. Moulet, T.T. Luu, S. Pabst, R. Santra, Z. A. Alahmed, A. M. Azzeer, V. S. Yakovlev, V Pervak, F. Krausz, E. Goulielmakis, "Synthesized Light Transients", in *Science*, Vol. 334, 199
2. Giovanni Cirmi, Giulio M. Rossi, Shaobo Fang, Shih-Hsuan Chia, Oliver D. Mucke, Christian Manzoni, Paolo Farinello, Giulio Cerullo and Franz X. Kartner, "High-Energy Sub-Optical-Cycle Parametric waveform Synthesizer", in *Ultrafast Phenomena XIX*, Proceedings in Physics 162 (2015)
3. Chih-Hsuan Lu, Yu-Jung Tsou, Hong-Yu Chen, Bo-Han Chen, Yu-Chen Cheng, Shang-Da Yang, Ming-Chang Chen, Chia-Chen Hsu, and A.H. Kung, "Generation of intense supercontinuum in condensed media", in *Optica*, Vol. 1, No. 6 (Optical Society of America, 2014), 400.