Nonlinear Optical Engineering

Stimulated Raman Scattering (3)
(NFO 5th ed: 8.4 ~ 8.5)

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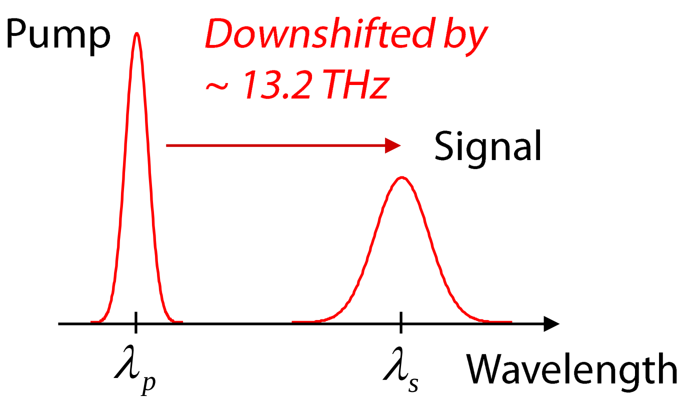
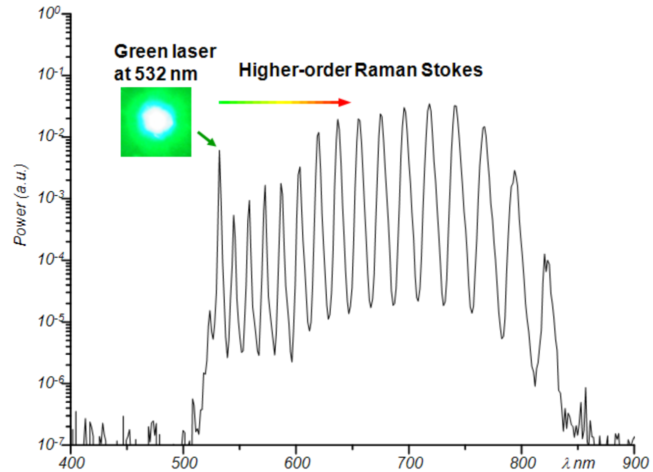
Soliton Effects (1)

Pump and Signal (Raman Stokes):





Pulse-propagation equations:

Coupled NLSE:

$$\rightarrow \frac{\partial A_p}{\partial z} + \frac{i\beta_{2p}}{2}\frac{\partial^2 A_p}{\partial T^2} = i\gamma_p\left[\left|A_p\right|^2 + (2 - f_R)\left|A_s\right|^2\right]A_p - \frac{g_p}{2}\left|A_s\right|^2 A_p$$

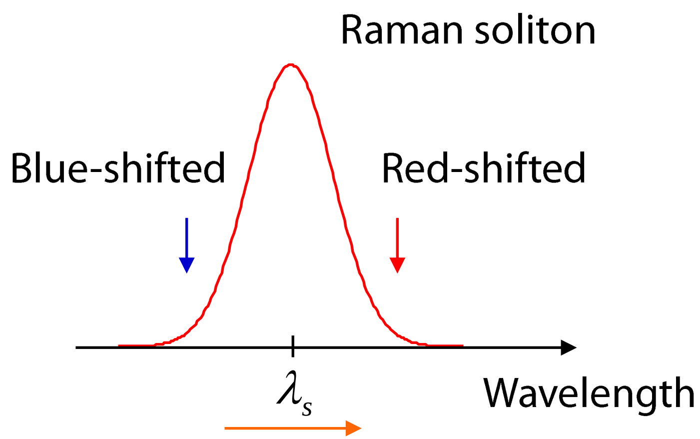
$$\rightarrow \frac{\partial A_s}{\partial z} - d\frac{\partial A_s}{\partial T} + \frac{i\beta_{2s}}{2}\frac{\partial^2 A_s}{\partial T^2} = i\gamma_s\left[\left|A_s\right|^2 + (2 - f_R)\left|A_p\right|^2\right]A_s + \frac{g_s}{2}\left|A_p\right|^2 A_s$$

$$\leftarrow T = t - z / v_{gp}, \quad d = v_{gp}^{-1} - v_{gs}^{-1}$$

Raman Soliton: Dispersion and SPM balanced

Soliton Effects (2)

Intrapulse Raman scattering:



Continuous energy transfer via Raman scattering from blue-shifted components to red-shifted components

NLSE:

$$\rightarrow i\frac{\partial u}{\partial \xi} + \frac{1}{2}\frac{\partial^2 u}{\partial \tau^2} + |u|^2 u = \tau_R u \frac{\partial |u|^2}{\partial \tau}$$

Spectral shift:

$$\rightarrow \Omega_p = -\frac{8T_R \gamma P_0}{15T_0^2} z = -\frac{8T_R |\beta_2|}{15T_0^4} z \qquad \leftarrow N = \gamma P_0 T_0^2 / |\beta_2| = 1$$

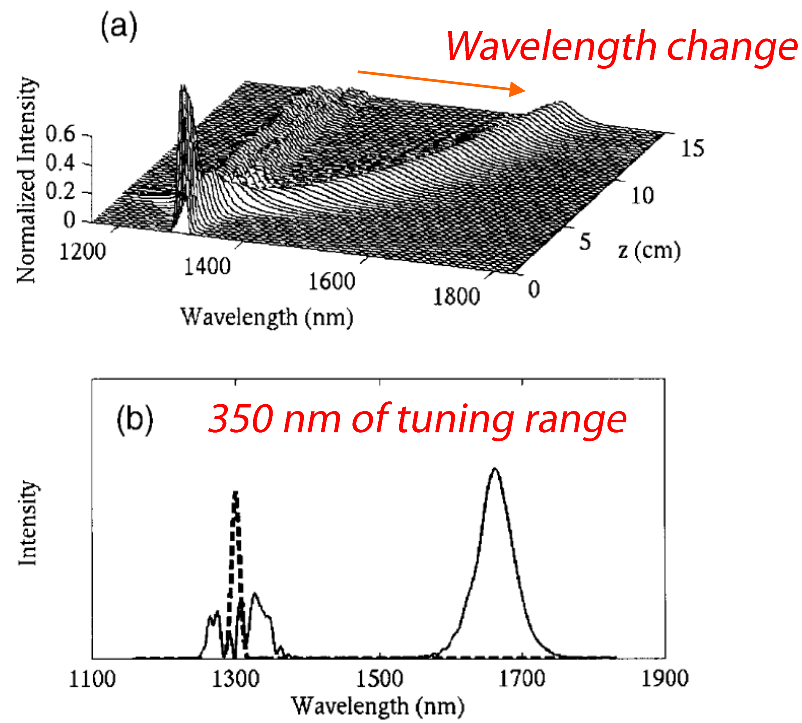


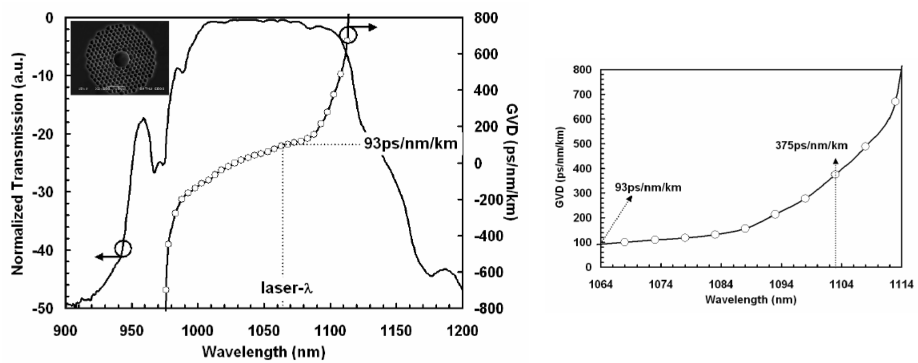
Fig. 3. (a) Simulated pulse-spectrum propagation in a 15-cm TASMF. (b) Input (dashed curve) and output (solid curve) spectra. Simulation parameters: $L_{NL} = 0.6$ cm, $L_D = 20$ cm, $L_D' = 25$ m, and $T_R = 3$ fs.

Opt. Lett. ***26****, 358 (2001)*

Soliton Self-Frequency Shift

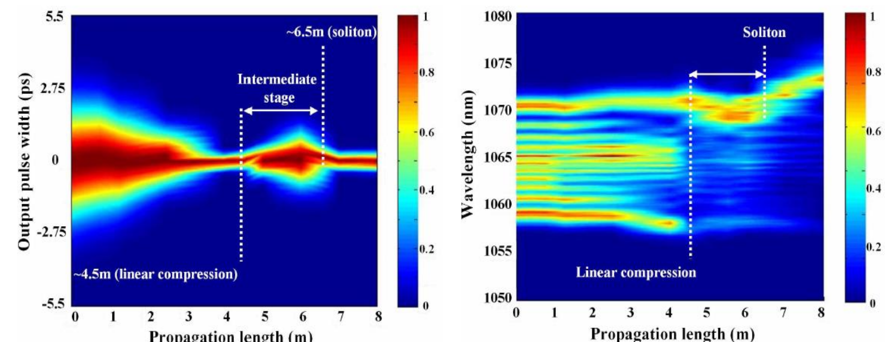
Photonic bandgap fiber with anomalous dispersion:

Optics Express ***16****, 2381 (2008)*



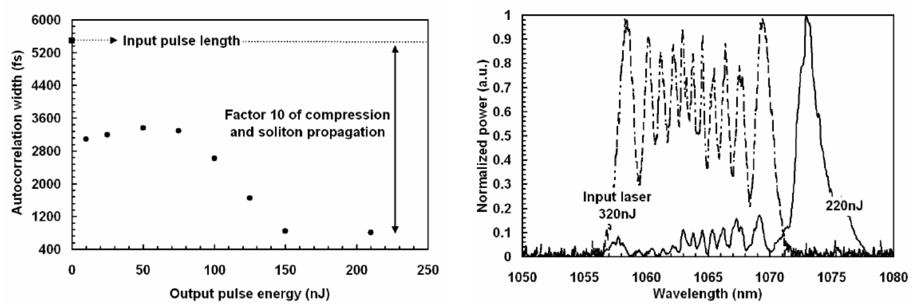
(a) (b)

Fig. 1. (a). Normalized transmission (solid curve) and GVD (circle points) versus the wavelength. Fiber cross-section used in the following experiments is shown in the inset.; (b) GVD zoom between 1064nm and 1114nm.



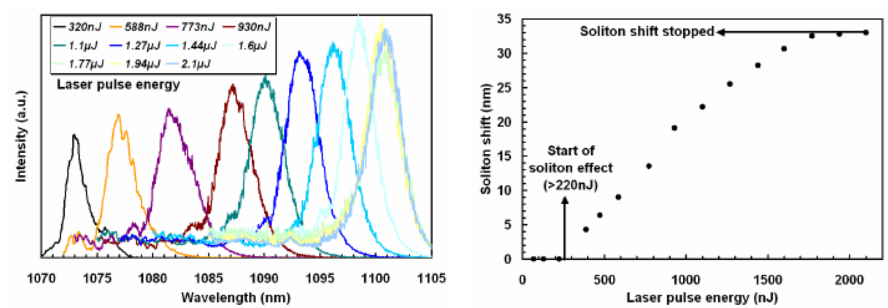
(a) (b)

Fig. 3. (a). Normalized experimental output pulse width and (b) spectrum as a function of the fiber propagation for 320nJ laser pulse energy. (Linear interpolation is used for the plot)



(a) (b)

Fig. 2. (a). Output pulse autocorrelation width (without deconvolution factor) as a function of output pulse energy; (b). Spectra before (dashed curve) and after (solid curve) propagation in 8m length of HC-PBGF for 320nJ laser pulse energy (220nJ×77%=170nJ-soliton).



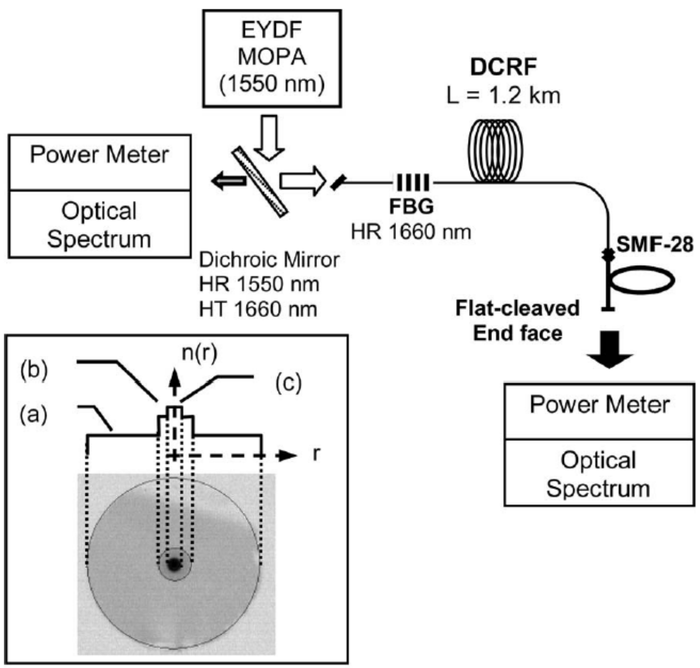
(a) (b)

Fig. 4. (a). Spectra recorded at the output of 8m length of HC-PBGF : zoom on the soliton part (residual pump at 1064nm not shown). (b) Soliton shift versus the laser pulse energy. The laser pulse energy threshold (>220nJ) relating to the soliton effect is also indicated.

Double-Clad Raman Fiber Lasers

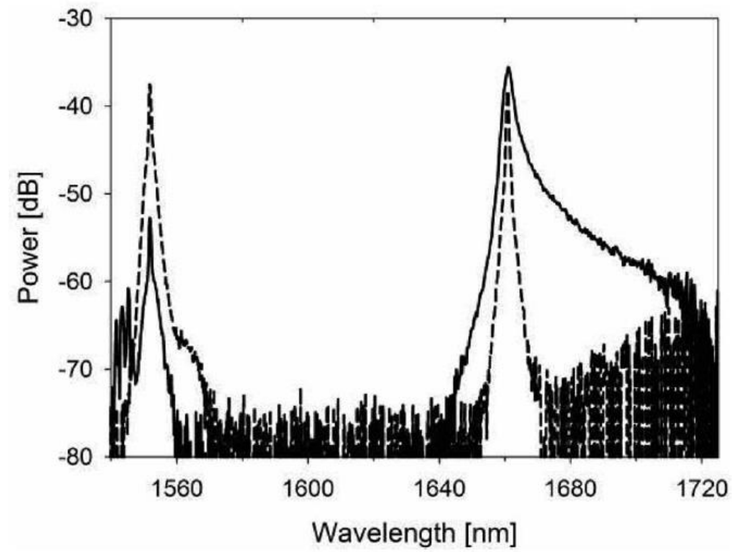
Inter-modal stimulated Raman scattering :

Opt. Lett. ***31****, 2290 (2006)*

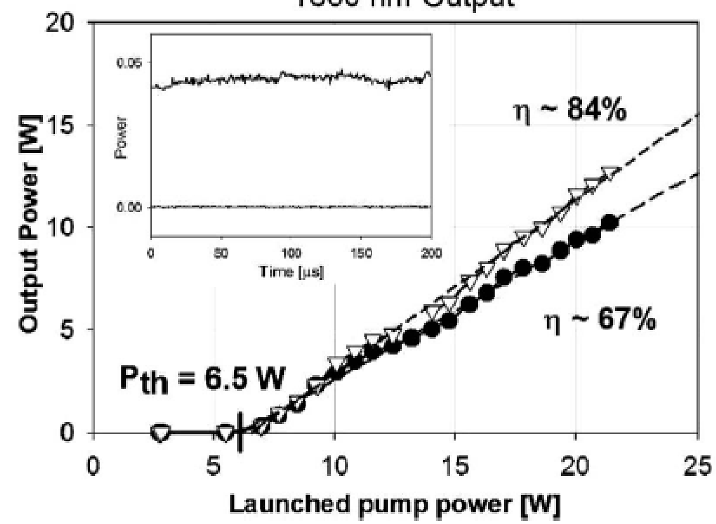


DCRF

Fig. 1. Experimental setup of the high-power cladding-pumped Raman fiber laser. Inset, double-clad Raman fiber idealized refractive index profile and cross section: (a) outer silica cladding; (b) germanium-doped inner cladding; (c) core.



1660 nm Output



Effect of Four-Wave Mixing

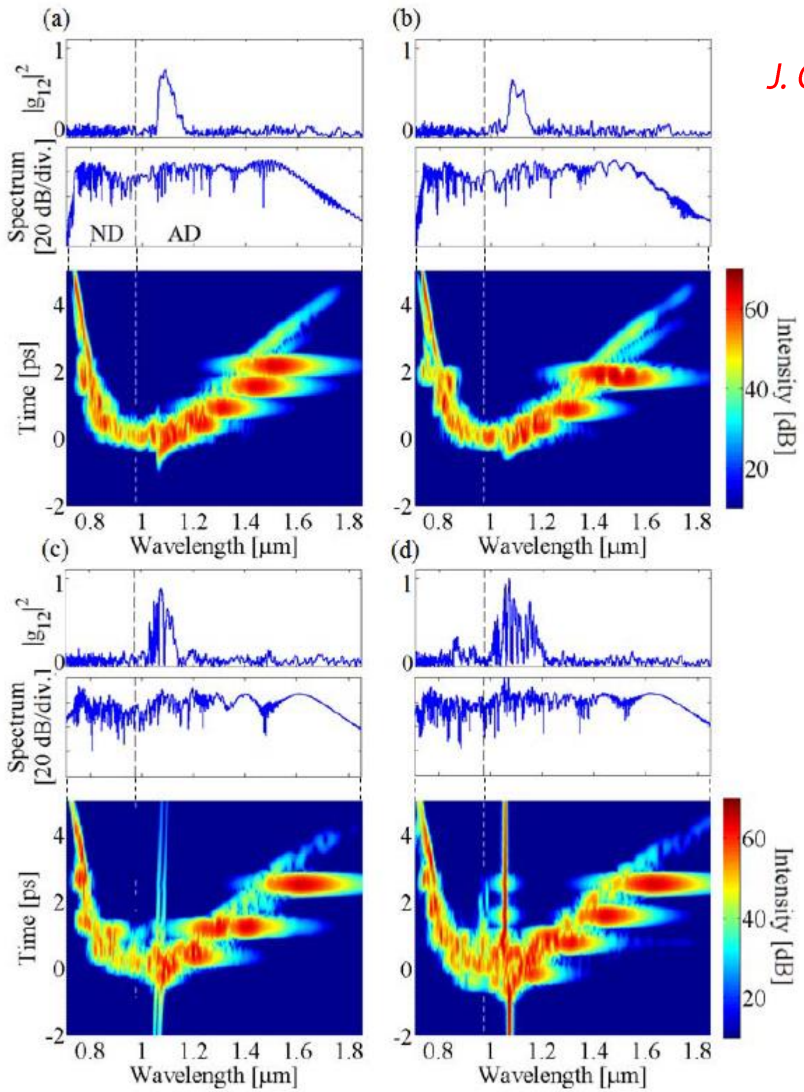


Fig. 3. Simulated spectrograms for (a) soliton, (b) Gaussian, (c) CS, and (d) CDS pulses after the propagation through PCF1. Each spectrogram is projected onto an aggregated spectrum at the output point. The top figures show the calculated MDOC as a function of wavelength. The vertical dashed-lines denote location of the ZDW.

J. Quant. Electron. ***52****, 6400311 (2016)*

Supercontinuum generation:

Based on a PCF with anomalous dispersion with a negative slope near a single ZDW