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Compact solid-state lasers for frequency comb generation

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Frequency combs: coherent conversion from the optical into the microwave regime



Creating a frequency comb: a phase stable mode locked laser



coherent octave spanning spectrum (supercontinuum, SC) mandatory → broadening of the laser spectrum in a highly nonlinear fiber → high peak power and **short pulses** required

heterodyning f_1 and f_2 gives a beat note of: $2f_1 - f_2 = f_{CFO}$

How short need the pulses to be?





Laser system	Soliton order N	detected f _{CEO} ?
ERGO + high β_2 fiber ERGO + low β_2 fiber	8 >30	
KGW direct pulses KGW + compression	13 5	
LuO-Thin Disk laser	6	

The spectral broadening of the pulses in the HNLF is theoretically described by Soliton fission.

For too long input pulses modulation instabilities dominate and noise is amplified leading to an incoherent SC, see a) below.

For short pulses the fission process is induced by higher order dispersion and Raman scattering, see b) below.

1300

1500



A simple guideline for a coherent broadening is given by the Soliton order: N < 10

This is confirmed by all three systems

Soliton order:

 $\sqrt{\frac{L_{\rm D}}{I}} = \sqrt{\frac{\tau_{\rm p} \cdot P_{\rm av}}{f_{\rm rep}}} \cdot \frac{\gamma}{|\beta_2|} \cdot 0.283$

nonlinear coefficient and 2nd order γ, β_2 : dispersion of the HNLF

J.M. Dudley et al., Rev. of Modern Physics 78, 1135 (2006)

