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Stimulated Brillouin scattering laser for precision satellite tracking

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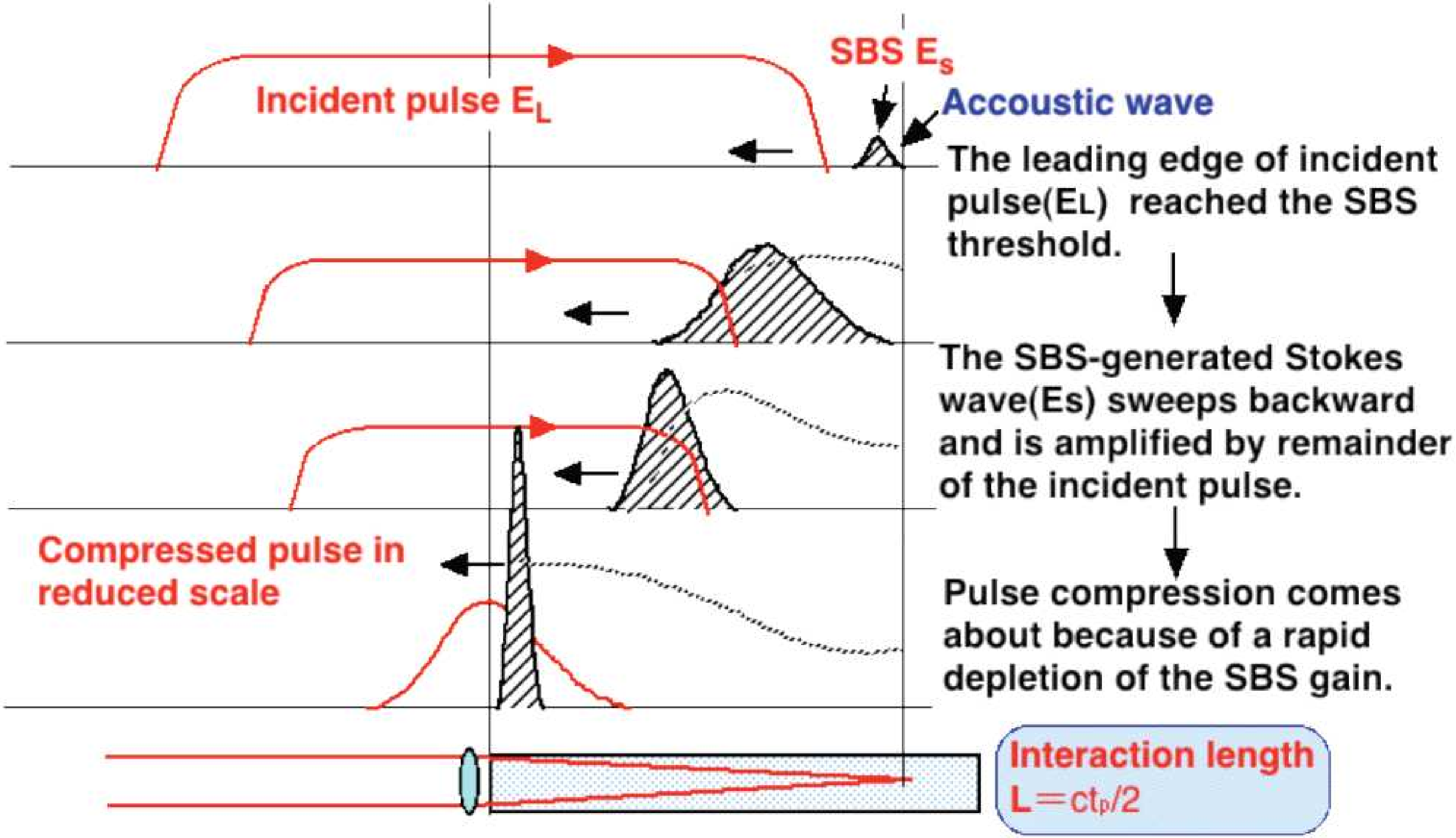
Picosecond Solid-state Lasers

- **mode-locked lasers - pulse energy ~ 1mJ, pulse width < 1 ps, but complex optical scheme;**
- **diode pumped microchip lasers - pulse width ~ 40-50 ps, but low pulse energy;**
- **lasers with SBS and SRS pulse compression – any pulse energy, pulse compression of passive Q-switched pulse to 1 ps, simple schematic decisions**

Brillouin (or Raman) pulse compression



The leading edge of incident pulse(EL) reached the SBS threshold.

The SBS-generated Stokes wave(Es) sweeps backward and is amplified by remainder of the incident pulse.

Pulse compression comes about because of a rapid depletion of the SBS gain.

Fluorocarbons as Brillouin media

SBS material

Liquid fluorocarbon (Fliorinert FC75)

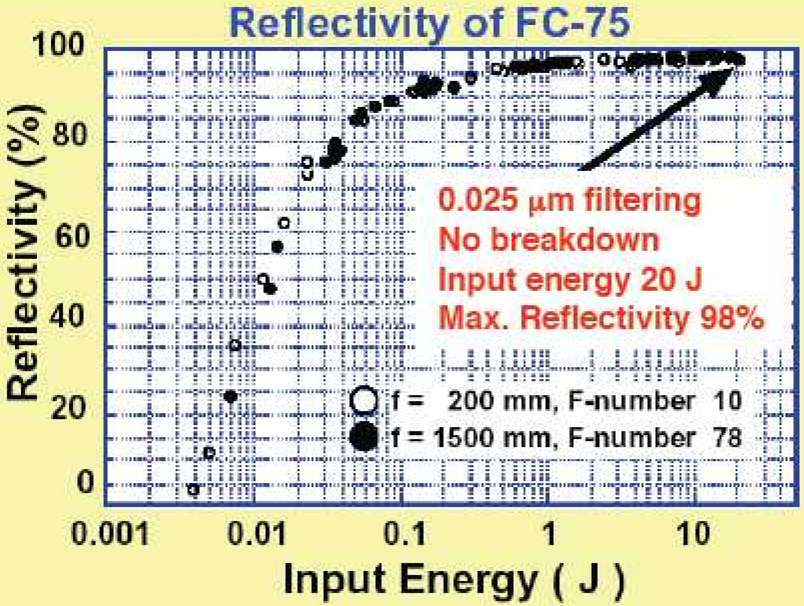
(1) Low absorption at laser wavelength
$(\alpha < 1\times10^{-6\sim7}/\mathrm{cm})$

(2) No impurities/micro particles
Precise cleaning & filtering

(3) High damage threshold
suppression of laser breakdown
(>100 GW/cm^2 @1 ns)

(4) Fast relaxation of accoustic wave
less than laser rising time
(0.9 ns @1.06 µm)

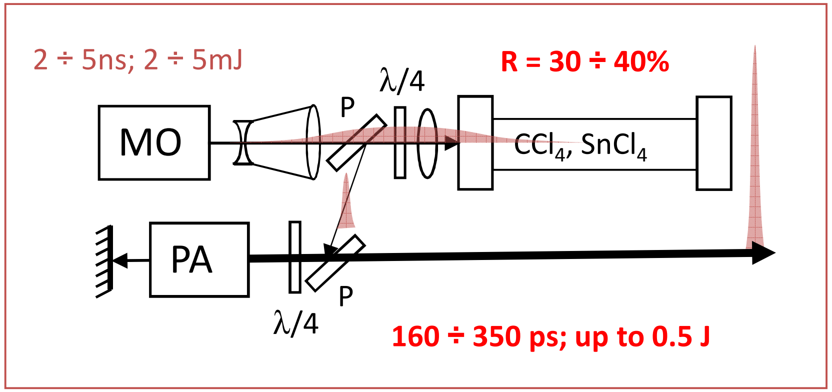
(5) High SBS gain for lower threshold
(7 cm/GW @1.06µm)



0.025 µm filtering
No breakdown
Input energy 20 J
Max. Reflectivity 98%

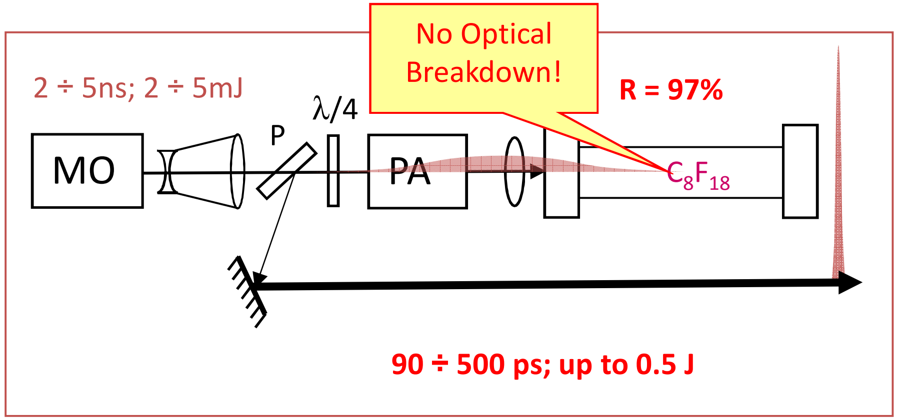
Schemes of SBS-lasers:

Conventional



- small SBS-mirror reflectivity
- small amplifier energy extraction
- thermal aberrations in Nd:YAG
- pulse compression up to ~ 150ps
- energy stability $StDev_{532nm}$ ~ 6.5%

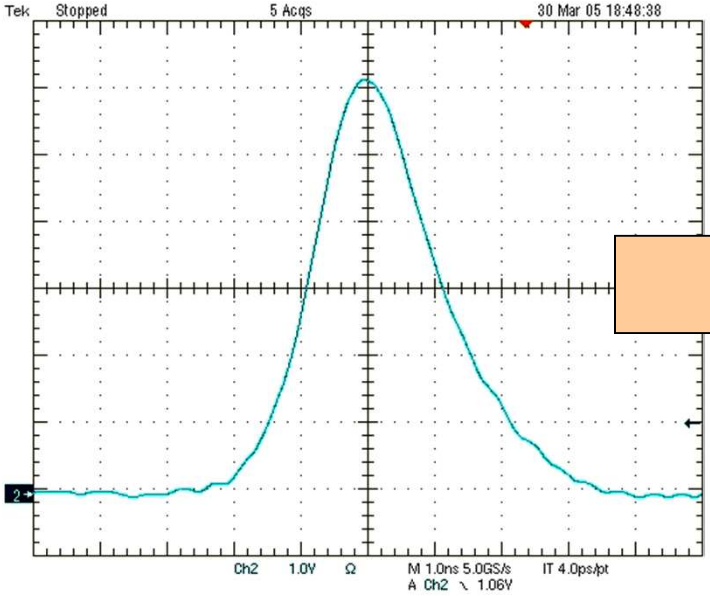
New, based on fluorocarbons



- SBS-mirror reflectivity > 97%
- Gaussian output beam profile
- phase-conjugated beam
- pulse compression up to ~ 90ps
- energy stability $StDev_{532nm}$ ~ 3%

Example of SBS-pulse compression

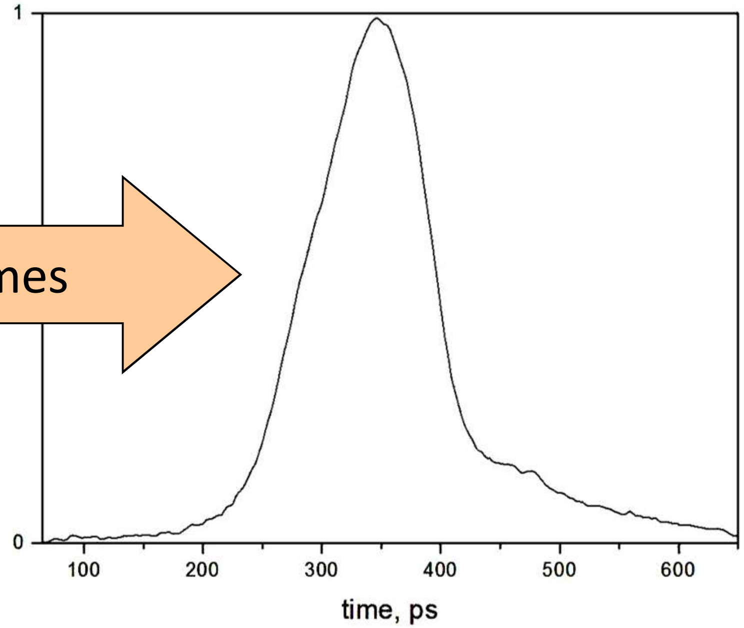
From MO: ~2ns, SLM



Tektronix, 1GHz

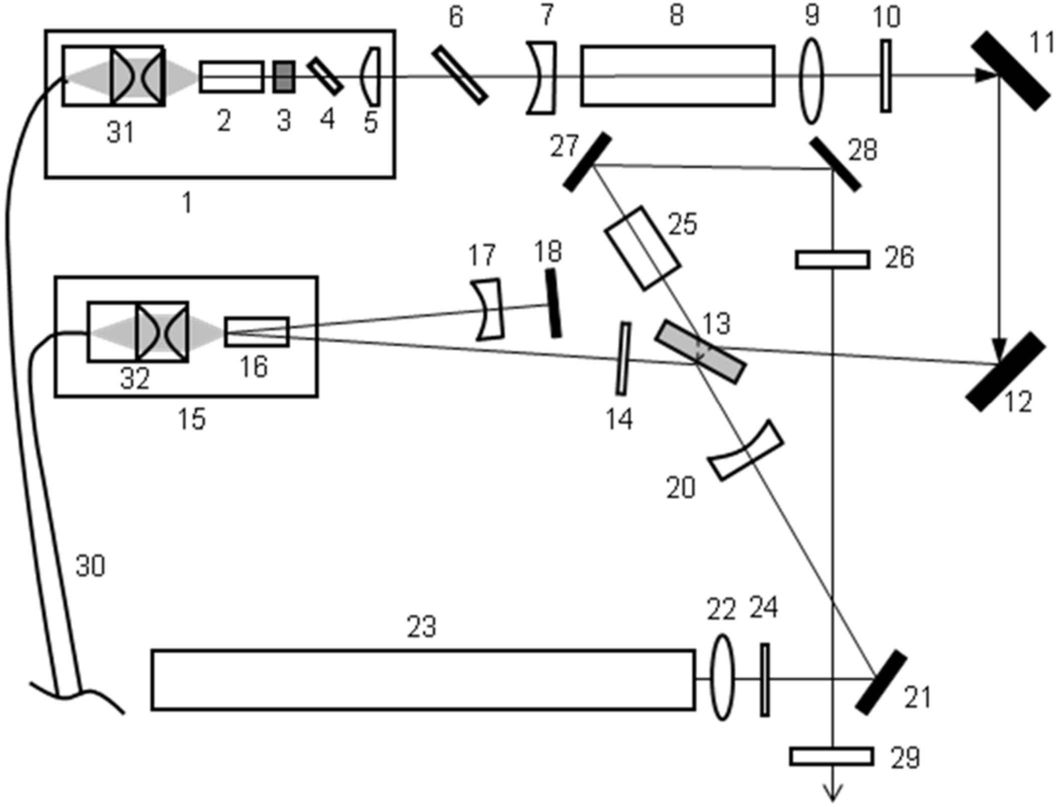
18 times

After SBS-Amplifier-Compressor: ~110ps



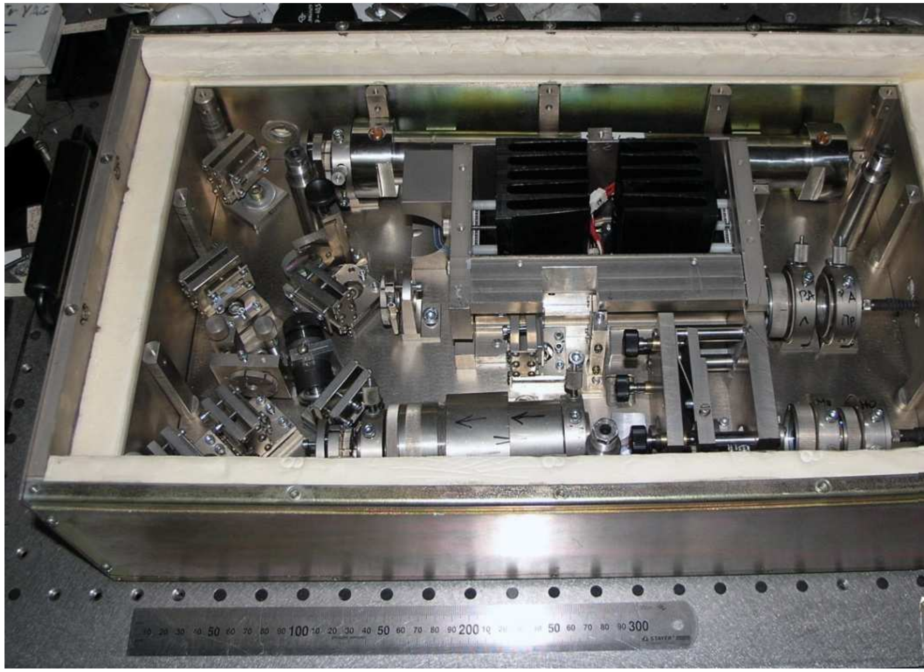
Hamamatsu, 2ps

Scheme of SBS-laser



(1) Master-oscillator;
(2) Nd:YAG AR@1064+HR@1064 / LR@808;
(3) Cr:YAG; (4) polarizer;
(5) spherical output coupler: resonator length ~30 мм;
(6) polarizer;
(7) +(9) beam expander;
(8) Faraday rotator;
(10) half-wave plate;
(11) и (12) turning mirrors;
(13) polarizer;
(14) quarter-wave plate
(15) power amplifier;
(16) Nd:YAG laser rod;
(17) compensating lens;
(18) back miror;
(20) negative lens;
(21) turning mirror;
(22) focusing lens;
(23) SBS –cell;
(24) quarter-wave plate;
(25) beam expander ;
(26) KTP crystal;
(27) +(28) turning mirrors;
(29) output window

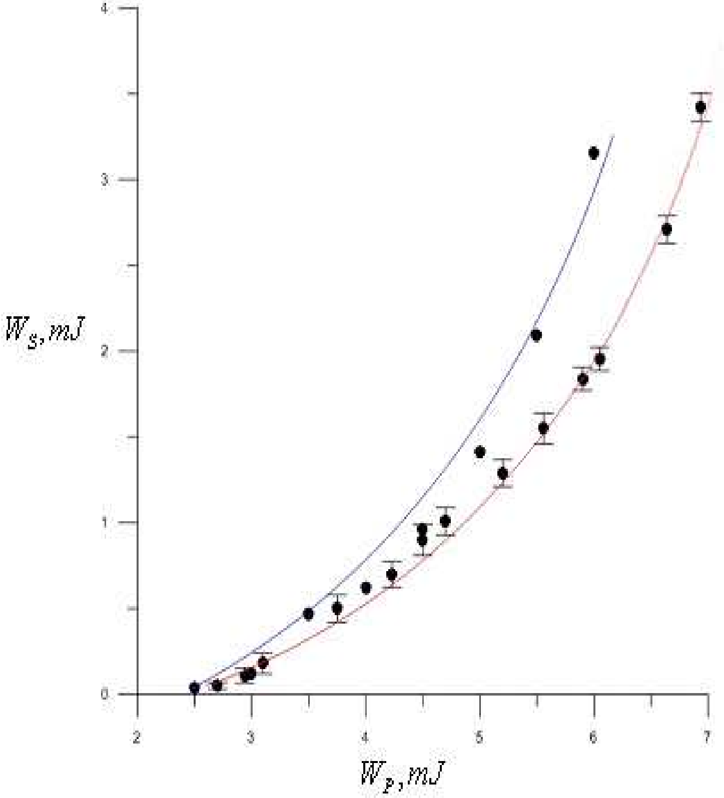
View of SBS-laser

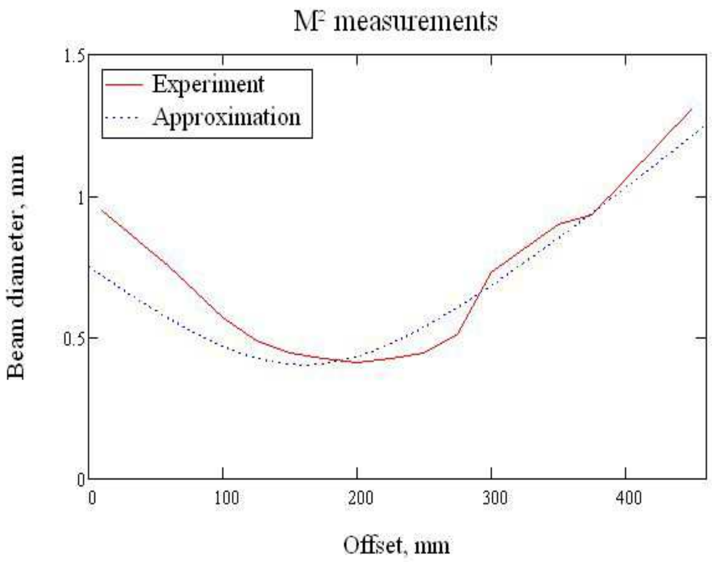


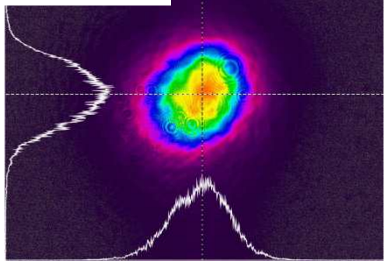
Dimensions: 520 x 315 x 150 mm^2

Temperature range: - 40^{0}C ÷ + 50^{0}C

Output energy and beam quality of SBS-laser





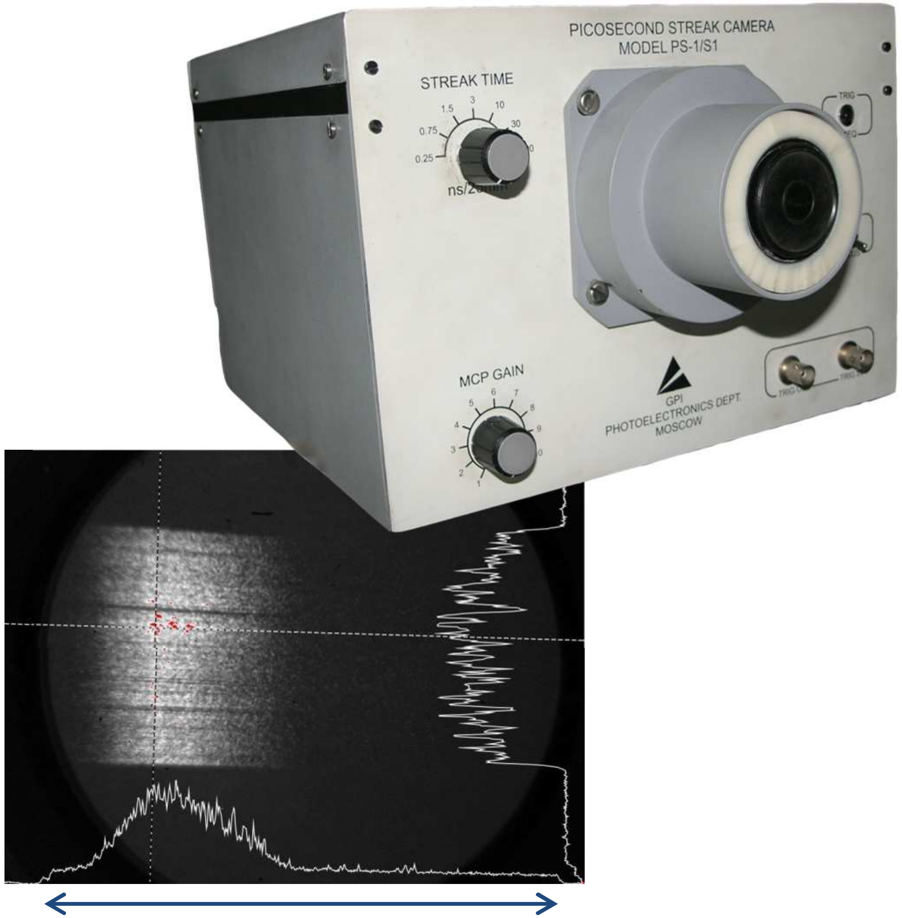


Beam quality **M^2 ≤ 1.2**
at output beam diameter
of **1.5 mm**

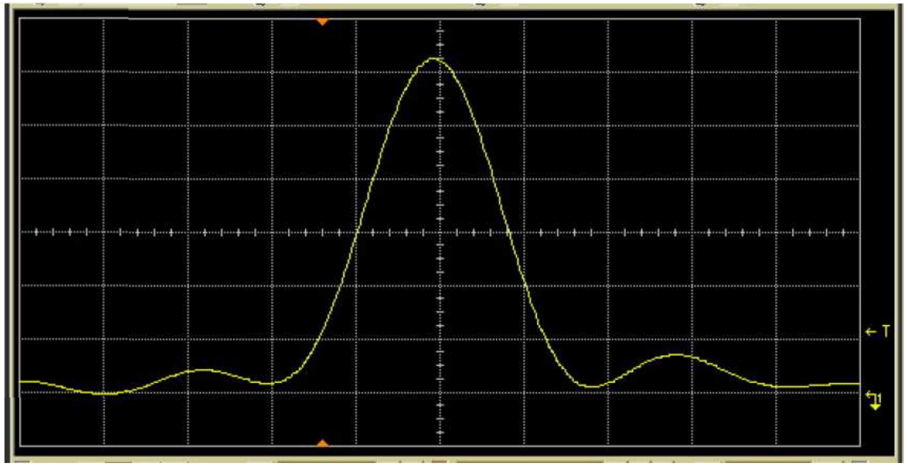
W_{532} ~ 2 mJ **at**

W_{sbs} = 3.5 +/- 0.02 mJ

Output pulse of SBS-laser



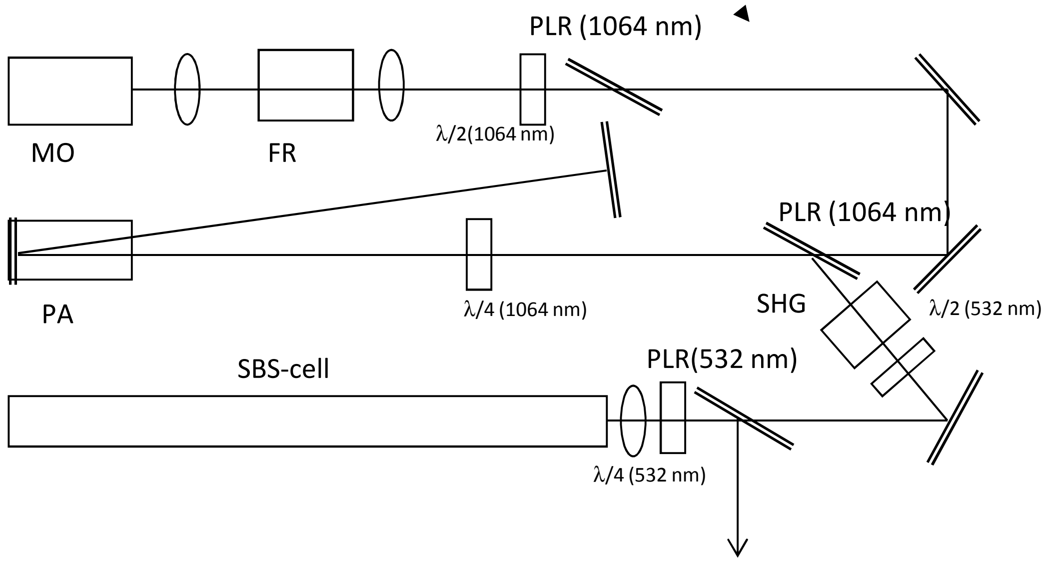
Measurements by streak-camera
(maximal resolution of 1 ps) **$\tau_{532\ nm} \approx 70 \div 80$ ps**



At measurements by LeCroy 820Zi

(8 GHz, 50 ps/div) $\tau_{sbs} \approx 90$ ps

Possible upgrade of SBS-laser



From theory: minimal SBS-compressed pulse $\tau_{sbs} \sim 0.1T_s$

Here period of hypersound wave $T_s = \lambda_L / 2v_s$

(λ_L – laser pump wavelength, v_s – hypersound velocity in Brillouin medium)

As for fluorocarbons $v_s \approx 500$ m/s so T_s (1064 nm) ≈ 1 ns

By transition to SBS at 532 nm we will have τ_{sbs} (532 nm) ≈ 50 ps