# Q - SWITCHED SBS - COMPRESSED ND:YAG LASER FOR SATELLITE RANGING

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Temporally compressed by backward stimulated Brillouin scattering (SBS) Nd:YAG lasers of series SL312 fit to the family of picosecond (PL2100 Series) and nanosecond (NL300 Series) lasers of EKSPLA Co. Maintaining a reliable, compact and cost-effective design of Q-switched lasers SBS compressor allows to achieve picosecond pulses of high energy. SL312 series lasers are powerful tools for applications in material research, satellite ranging, lidar, spectroscopy, surface treatment, LIF, etc. Passively Q-switched short-cavity oscillator is a heart of system, providing $TEM_{00}$, single axial mode output pulse. Liquid cell is used for backward SBS of nanosecond pulse generated by master oscillator. Compressed pulse is directed into amplifier with polarization rotation before the last pass for efficient extraction of stored in the rod energy. Near Gaussian amplified pulse is optionally converted into second harmonics. Angle-tuned KD*P crystal in oven used for harmonics generation. Harmonics separation optics is employed to obtain separate fundamental, and second harmonic beams at the laser output. Optional second cascade of compression after the second harmonic generator allows to obtain pulses of 30 ps and 10 mJ at 630 nm.

Power supply and water/water type cooling units are performed in standard 19“ rack design. A new design with water/air cooling unit is available now. The whole powering group is optimized for reliable operation with laser head, and requires just small space under user’s optical table.

## LASER OPTICAL SCHEME AND PRINCIPLE OF OPERATION

The laser head comprises four functional parts (Fig. 1):

I. Master oscillator.
II. System of optical pulses compression.
III. System of optical pulses amplification.
IV. System of harmonics generation.

Fig. 1. Schematics of the laser head

## II. Master oscillator

Fig. 2. Schematics of master oscillator

Master oscillator (see Fig.2) is mounted in the separate compartment of a rigid design ensuring mechanical and thermal stability. Its resonator is formed by 100 % reflectivity mirror (1) and uncoated glass Fabry-Perot etalon (8). GSGG:Cr crystal passive Q-switch (2), polarizer (3), Nd:YAG rod of ∅ 3 × 60 mm (5), aperture (6) and two quarter wave plates (4,7) are placed within the resonator. Aperture (6) selects a single transverse mode, while Fabry-Perot etalon (8) with two quarter wave plates enables selection of a single longitudinal mode. Master oscillator radiates $TEM_{00}$ pulses with a smooth envelope and featuring ~ 2 ns duration and 4÷5 mJ energy. High long-term stability of pulse parameters achieved by using invar resonator rods and Fabry-Perot etalon thermostabilisation.

## II. Compression system

The nonlinear optics phenomena - stimulated Brillouin scattering (SBS) is the simplest way to have pulse compression from nanosecond to picosecond diapason. No complicated electronics devices are required in this case. Pulse compressor (see Fig. 1) consists of quarter wave plate (Iλ/4), focusing lens (L2), SBS-cell with $CCl_4$ liquid inside, polarizer (P1).

A linearly polarized master oscillator (I) pulse passes through quarter wave plate acquiring circular polarization and is focused into SBS-cell by lens (L1). Focusing is arranged in the way to compress the Stokes pulse down to ~ 130 ps via backward stimulated Brillouin scattering (SBS) process. The backscattered Stokes pulse, as its phase is reversed, strictly repeats the path of pump (master oscillator's) pulse in the opposite direction and reversal divergence. The compressed pulse is collimated by lens (L1) and passes the wave plate (Iλ/4) which transforms polarization of Stokes radiation into linear and perpendicular to the polarization of master oscillator radiation. After this, polarizer (P1) and mirror ( R1) directs the beam out of the compressor into the amplification stage.

## III. Amplification system

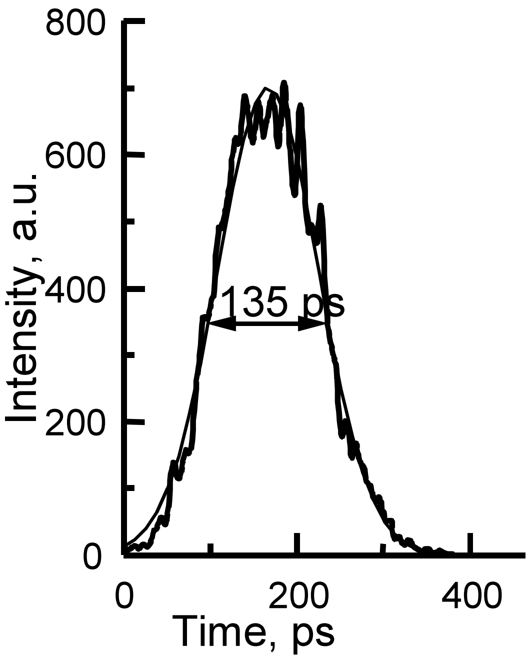
Triple-pass optical amplification system uses Nd:YAG rod measured ∅ 10 × 100 mm. Mirror (R1, R2) arrange the first pass through the amplifier. Then telescope (L2, L3) expands the beam up to ~ 10 mm in diameter, and by means of mirror (R3), polarizer (P2) mirror (R4) the next two passes through amplifier are organized. The quarter wave plate (IIλ/4) outcouples amplified pulse through polarizer (P2).

## IV. Harmonics generation

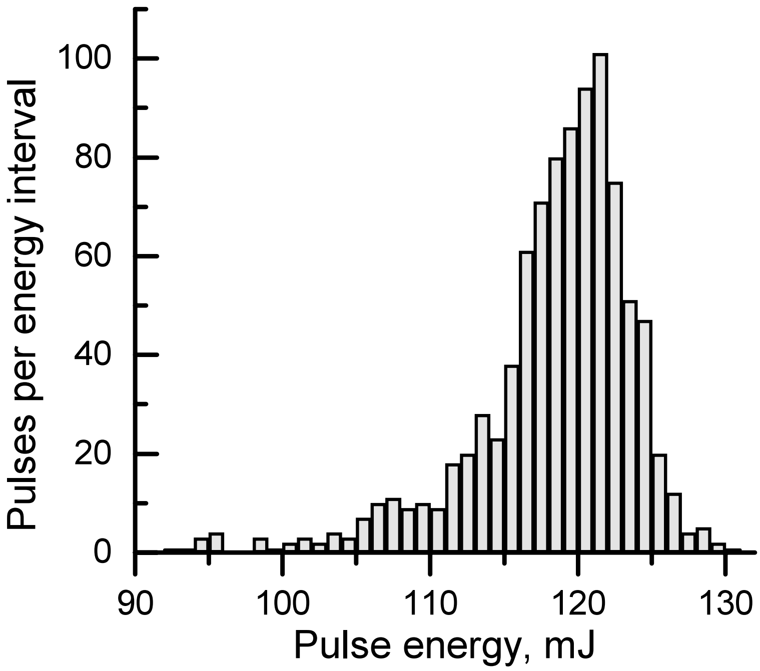
The second harmonics generation is realized in K*DP (Fig. 1) crystal mounted on adjustable support with temperature stabilisator who allows long term stability of frequency conversion. The half wave plate (λ/2) allows to change polarization angle of fundamental radiation. One may obtain two different wavelength pulses at a time, i.e. the fundamental and the second. The pulses of different wavelengths are separated by dichroic mirror (R5) and emerge from output aperture from laser frame. Special designed device for "start" signal can be included inside or outside the laser head.

**SPECIFICATIONS**

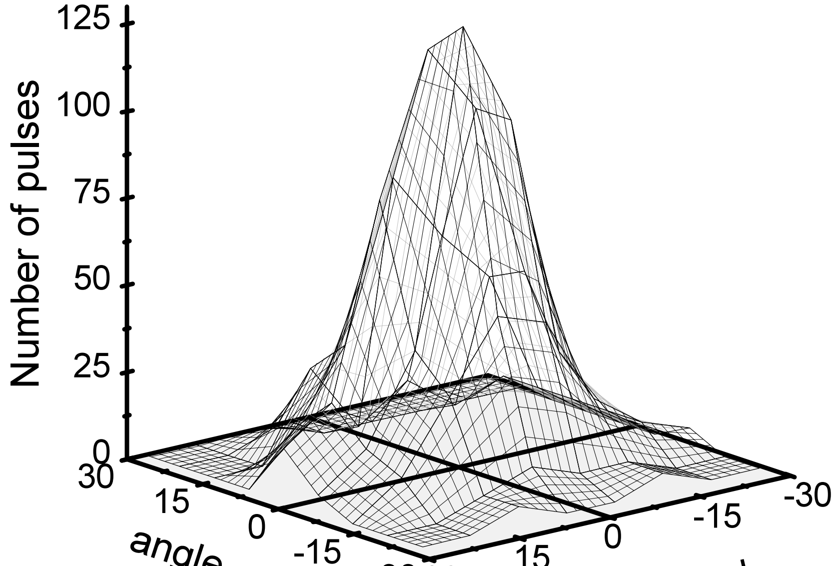
| | | |
|---|---|---|
| Wavelength, nm | 1064 / 532 | |
| Pulse energy, mJ | 250 / 100 | 500 / 260 |
| Pulse duration, ps | 130 ± 20 | |
| Stability of pulse energy, % (90% of pulses) | ± 5 /± 8 | |
| Beam mode | Near Gausian | |
| Beam diameter, mm | 10 | 12 |
| Repetition rate, Hz | Up to 10, fixed | Up to 5, fixed |
| Dimensions, mm:<br>Laser head<br>Electrical cabinet | <br>650 x250 x 145<br>550 x 600 x 530 | |
| Service requirements:<br>Powering<br><br>Water inlet, l/min | <br>380 V, 3 phase, 2.5 kVA or<br>220 V, 1 phase, 2.5 kVA<br>10; max 20 °C | |




**Pulse temporal shape, registered with streak camera „AGAT“ and computerized CCD array**




**Statistics of output energy @532nm histogram in series of 920 pulses:**




**Results of beam pointing measurements using CCD camera at the focus of 2m-focal-length lens (1250 pulses)**

## APPLICATION TO SATELLITE LASER RANGING

Laser pulse generator, mentioned above, more as two years is being used at the Riga SLR station of Astronomical Institute of University of Latvia, as main unit together with laser telescope LS-105. System is working in a multi-photon signal receive mode, with free aperture diameter of 90 cm using 532.0 nm wavelength.

High-energy light pulses are very efficient to get a maximum efficiency of returns by, usually; average sky conditions at latitude 57°N and close to the Baltic Sea.

Using 5 Hz pulse repetition rate we have got more than 8000 returns from Lageos by pass duration of 40 minutes, and more as 2000 returns from GPS-35 satellite during one hour ranging time. For some satellites, like GFZ-1, ZEIA, WESTPACK, TIPS, and low elevation passes from ERS satellites 10 Hz PRR is used.

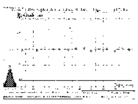


**Fig. 3. Typical distribution of returns, single shot error, location of normal points and normal points M.S.E. for one of LAGEOS passes.**

Average single-shot accuracy, at the current moment, gives 26 mm. Average normal points M.S.E. for all ranged satellites are approximately 5 – 7 mm.

As a positive property of SL-312 type laser pulse generator is a relatively simple adjustment of the unit also after general cleaning of quantrons or flashlamps exchange.

In a real exploiting procedure the maximum peak energy of 120 mJ is only sparse used. Usually we do satellite ranging with pulse energy between 90 and 100 mJ. That ensures long period stability of output pulse energy without additional adjustments.