N94-15612

The new MTLRS Transmitting System

P. SPERBER, U. HESSELS, R. MOTZ
INSTITUT FÜR ANGEWANDTE GEODÄSIE
FUNDAMENTALSTATION WETTZELL
D-8493 KÖTZTING
GERMANY

W. BEEK, J.W. OFFIERSKI, C. VAN ES
DELFT UNIVERSITY OF TECHNOLOGY
KOOTWIJK OBSERVATORY FOR SATELLITE GEODESY
POSTBOX 581, 7300 AN APELDOORN
THE NETHERLANDS

Abstract

This paper presents a detailed description about the new transmitting system of the Modular Transportable Laser Ranging Systems MTLRS-1/2. A simplified theory of the Self Filtering Unstable Resonator (SFUR) is explaned. Laser design details are discussed concerning the extreme environmental conditions in which these mobile systems are operating. Details are given concerning the new avalanche START detector. The new SFUR laser and START detector are necessary parts in order to bring both mobile systems towards 1 cm ranging accuracy.

1. Introduction

Since 1984 the two European Modular Transportable Laser Ranging Systems MTLRS-1, operated by the Institute for Applied Geodesy (IfAG, Germany), and MTLRS-2, operated by the Delft University of Technology (DUT, The Netherlands), have supplied the international network with laser ranging data from sites in Europe, CIS (former USSR) and North America. To improve the ranging accuracy from 5 cm to the 1 cm level, both systems carried out a major upgrade in 1991. The main part of this upgrade was the exchange of the transmitting system consisting of the Laser and the Start Detector (The German MTLRS-1 system also upgraded the receiver package [1].

2. The Laser

The accuracy and the number of returns produced by a satellite laser ranging system is mainly influenced by the duration and energy of the emitted laser pulses. To improve these two points, the original Nd:YAP laser (370 ps FWHM pulse-duration, 10 mJ pulse-energy at 539 nm) was exchanged for a new Nd:YAG laser (30 ps FWHM pulse-duration, 30 mJ pulse-energy at 532 nm). To realize this high demands with a simple and reliable optical configuration, a new resonator setup, the Self Filtering Unstable Resonator (SFUR) [2,3] was used. Together with a simple optical setup, this resonator has the advantage to be less sensitive to optical adjustments and operates with a very homogeneous spatial pulse-shape, minimizing the danger of destroying optical components at high resonator energy output levels.

2.1 Simplified SFUR Theory [4]

Fig. 1 shows the principle of the SFUR resonator.

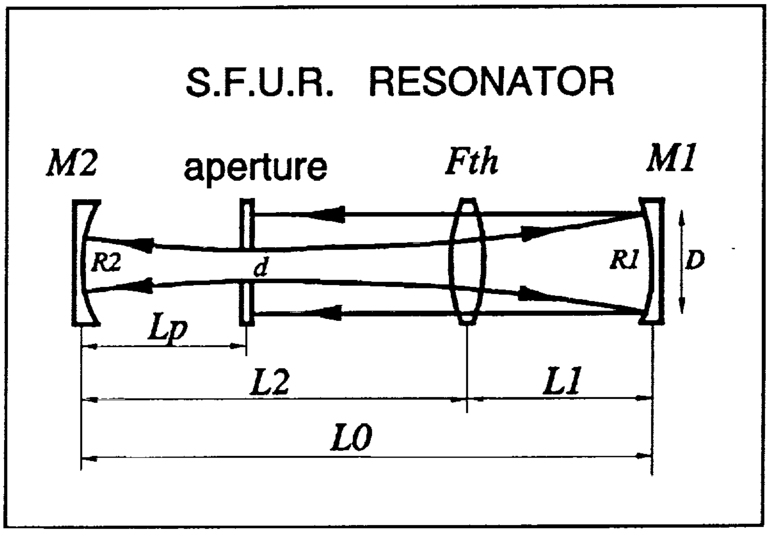

Fig. 1

Two mirrors M_1 and M_2 are forming an instable, confocal resonator:

$$R_1 + R_2 = 2 \cdot L_o$$

R_1 and R_2 are the (concave) radii of the mirrors and L_o the optical resonator length. This resonator configuration generates a spot in the resonator, which usually destroys optical elements. If a small pinhole is placed in this focal point this problem disappears and some major advantages can be seen. The diameter d of the aperture has to be chosen in a way, that only the central lobe of the Airy pattern (generated by mirror M_2) propagates to M_1.

$$d = \sqrt{2.44 \cdot f \cdot \lambda}$$

(f: focal length of M_2, λ: laser wavelength)

The mode, generated by the central maximum of the Airy pattern has a smooth, nearly Gaussian shape, with zero intensity at radius r_0 where

$$r_0 = - M \cdot \frac{d}{2} \qquad (M = - \frac{R_1}{R_2})$$

If the parameters of the resonator are correct, the mode is exactly filling the whole volume of the active medium. Therefore nearly all the energy stored in the rod is converted into the laser pulse. The outcoupled pulse-energy is much higher compared to usual resonator configurations. The aperture (typical diameter $d \leq 1$ mm) gives a strong spatial filtering at each round trip smoothing the energy distribution in the beam and avoiding hot spots. In an exact analysis of the SFUR configuration the influence of the thermal lens (f_{th}: focal length) in the laser rod has to be taken into account.

$$L_0 = L_1 + L_2 - \frac{L_1 \cdot L_2}{f_{th}}$$

$$g_1 = 1 - \frac{L_0}{R_1} - \frac{L_2}{f_{th}}$$

$$g_2 = 1 - \frac{L_0}{R_2} - \frac{L_1}{f_{th}}$$

$$g = 2 \cdot g_1 \cdot g_2 - 1$$

$$M = g - \sqrt{g^2 - 1}$$

(L_1 and L_2 are the distances of M_1 and M_2 to the virtual position of the thermal lens). The optimum position L_p (distance from M_2) of the aperture, the diameter d of the aperture and diameter D of the laser beam are given by:

$$\frac{1}{L_p} = \frac{1}{R_2} + \frac{\sqrt{g^2 - 1}}{2 \cdot g_1 \cdot L_0}$$

$$d = \sqrt{4.88 \cdot L_p \cdot \lambda \cdot \left(1 - \frac{L_p}{R_2} \right)}$$

$$D = 1.5 \cdot M \cdot d \cdot \left(1 - \frac{L_2 - L_p}{\frac{1}{\frac{2}{R_2} - \frac{1}{L_p}} - L_p} \right)$$

2.2 Technical Realization

The laser system consists of four separate units, the laser head, the power supply with electronics, an external dye-cooling unit and the control panel.

A schematic drawing of the laser head is shown in Fig. 2. To save place, the SFUR Resonator M_1 - M_2 is folded over a prism PR. Picosecond pulses are generated with an acousto-optic modulator AML and a bleachable dye (Kodak 9740 in 1,2 Dichloroethane) (PML). The intense 30 ps long pulse is cavity dumped by the pockelscell PC and two polarizers PO. Because of the high energy of the output pulse of a SFUR resonator a single stage amplification (AMPL) is sufficient to get 100 mJ per pulse in the infrared. The second Harmonic Generator SHG converts about 40% of the energy into green light at 532 nm. The two wavelengths are separated by the dichroic mirror M_4. The excessive use of diagnostic diodes and motor driven micrometers allows the fine adjustment of the laser without opening the dust cover. Even the spatial shape of the pulse is monitored by a CCD - Camera. For maximum mechanical stability, the whole laser head is built on a temperature controlled, reinforced invar plate.

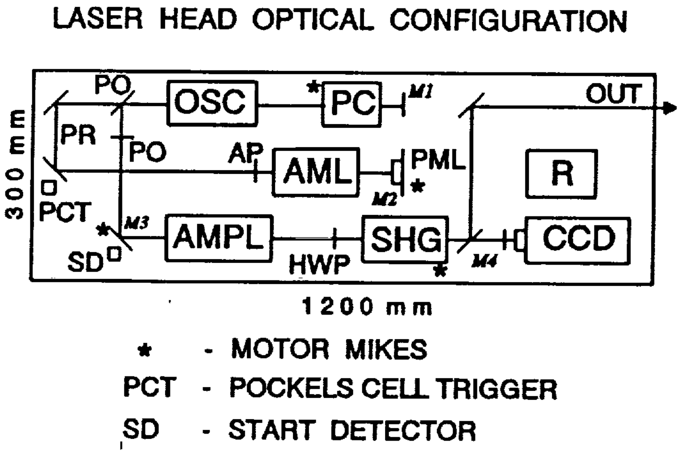

Fig. 2

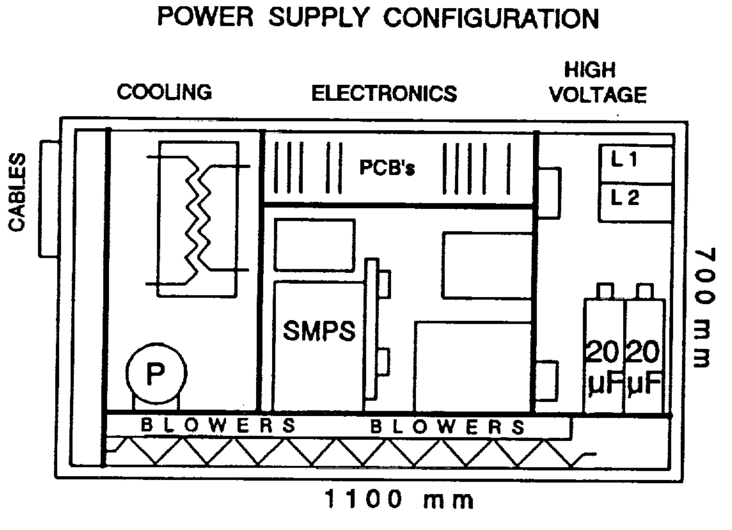

Fig. 3

Fig. 3 shows an inside picture of the power supply. The power supply and control electronics are also built in an isolated, temperature stabilized housing. The laser switches automatically between 380 V/50 Hz and 460V/60 Hz input, and the 3 phase power consumption is 5 KVA. Two independent control panels for the laser can be used; one for the Cabin, in use during ranging, and another one in the Cart for maintenance purposes.

Fig. 4 shows the laser temperature control system. The telescope together with the laser are built in the Cart which is located in full sunshine in the middle of the concrete platform (Pad). During satellite tracking this Cart is open and because of extreme environmental conditions (-20°C to +40°C), considerable attention is given to the stability and reliability of the laser (komacel-isolation of the head and power supply, excellent mechanical stability of all optical components). The heat generated by the flashtubes in the secondary cooling system is exchanged to the primary cooling system by means of an internal water to water heat exchanger connected to an external water flow with temperatures between 5-16°C.

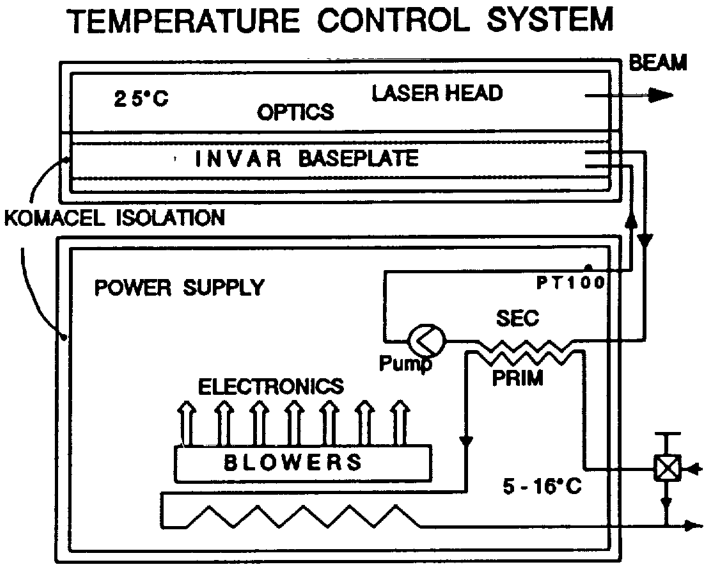

Fig. 4

The laser was first tested under field conditions during the campaign of MTLRS-1 in CIS (Common wealth of Independant States - the former USSR). The experiences were excellent.

The specifications of the laser are summarized in Fig. 5.

LASER SPECIFICATIONS

Wavelength	532 nm
Pulse energy	30 mJ
Pulse width	30 ps
Rep. rate	20 pps (max)
Divergence	0.4 mrad
Mode locking	active + passive
SHG	KD * P
Beam diameter	7 mm
Environment	- 20°C to +40°C
Power	5 kVA
Voltage	380/460 - 5A/ph.

Fig. 5

3. Start Detector

To start the time interval counter with high accuracy, the optical output signal of the laser has to be converted with minimum jitter to an electrical pulse, which is used in the start channel of the counter. Until 1990 this problem was solved in the MTLRS in the conventional way: a part of the green pulse was sent to a fast photo diode which generates an electrical pulse with an amplitude corresponding to the energy of the laser pulse which is fluctuating from shot to shot. These amplitude fluctuations were compensated by a constant fraction discriminator. Changes in the temporal pulse shape and strong energy fluctuations in this setup caused errors in the start-channel of the counter.

To minimize these errors, an optically triggered avalanche diode [5,6] was integrated into the system. This diode delivers an output signal with a constant amplitude independent on the energy of the laser pulse. The output signal is directly used as startsignal for the counter, a constant fraction generator is superfluous. Furthermore, to introduce high stability and the possibility to vary the pulse energy during tracking, the start diode is placed before the amplifier (behind mirror *M3* in Fig. 2) to detect the infrared light. Fig. 6 shows the output signal of the start diode which has a risetime of 300 - 400 ps and the jitter between optical and electrical pulse is less than 20 ps.

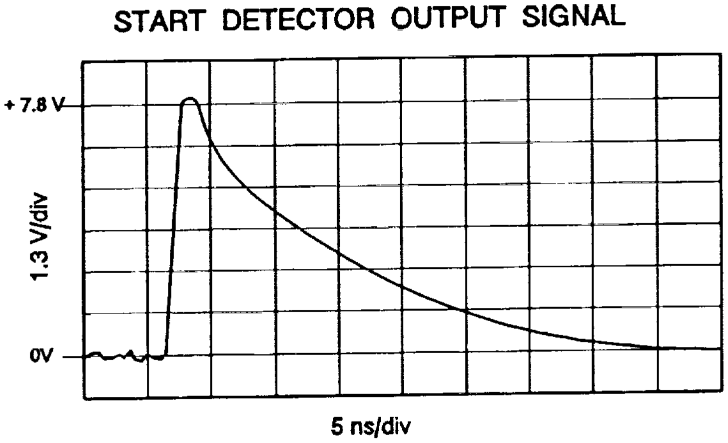

Fig. 6

In order to get stable results from the avalanche start detector under field conditions, the fibre together with the electronics have to be built inside the laser head where the temperature of the optical bench is stabilized at 25°C.

4. Summary

The upgrade of the transmitting part of MTLRS-1/2 formes the basis to improve the ranging accuracy of the systems significantly and makes them again some of the most advanced SLR systems worldwide.
First tracking results [7] show, that the system's single shot accuracy is about 1 cm after the upgrade of the receiver package which is already completed in MTLRS-1.

References:

[1] The new MTLRS-1 Receiving System, 1992 by P. Sperber, U. Hessels, R. Motz, in this Proceedings.

[2] Paper 1989 by A. Bianchi, A. Ferrario, P.G. Gobbi, C. Malvicini, G.C. Reali, SPIE 701, p.132.

[3] Paper 1987 by K. Hamal, V. Hraskova, H. Jelinkova, CLEO'85 Proceedings p.82, WE 4.

[4] Paper 1989 by C. Malvicini, A. Ferrario, G. Gabetta, G.P. Banfi, G.C. Reali, Proceedings of the seventh international Workshop on Laser Ranging Instrumentation p. 181.

[5] Paper 1990 Subcentimeter Single Photon Ranging All Solid State Detection Package, by I. Prochazka, K. Hamal, B. Sopko.

[6] Paper 1989 by I. Prochazka, K. Hamal, B. Sopko, Proceedings of the seventh international Workshop on Laser Ranging Instrumentation p. 219.

[7] Results of the MTLRS-1 Upgrade by P. Sperber, L. Amberg, L. Beyer, G. Blenski, W. Etling, U. Hessels, R. Motz, in this Proceedings.