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*The jubilee-logo will be used throughout the year on the web, printed matters and most of our correspondence.*

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## The Swiss Physical Society celebrates its 100<sup>th</sup> Anniversary

***All Swiss physicists are invited to join the ceremonial act,  
surrounded by a huge physics party on Friday, 27<sup>th</sup> June 2008, Kultur Casino Bern***

This year 2008 the Swiss Physical Society (SPS) celebrates its Centennial. Over its 100 years of existence the SPS grew up to a society with more than 1200 members, university professors, teachers, PhD students and other professionals from research laboratories and industry, all linked by their interest for physics. Famous members of the Society are Nobel laureates like Charles-Edouard Guillaume, Albert Einstein, Wolfgang Pauli, Felix Bloch, Karl-Alex Müller and Heinrich Rohrer.



*Meeting of the Swiss Natural Science Society 1908 in Glarus. Source: Burgerbibliothek Bern.*

The Swiss Physical Society was founded in 1908, during the annual meeting of the Swiss Natural Science Society in Glarus, as part of a wave of new, independent scientific societies, which included the Chemical Society and the Mathematical Society. All of these newly established societies were offshoots of the Swiss Natural Science Society, which had existed since 1815. On the occasion of its 100<sup>th</sup> anniversary, the Swiss Physical Society can look back on a remarkable history. Nearly all important Swiss physicists of the last 100 years were members. As early as in 1908, the year of its founding, the society's roster included such famous names as Marcel Großmann, Walter Ritz, and Albert Einstein.

A special Centenary celebration event will be organized on June 27<sup>th</sup> in Bern at the Kultur Casino, in presence of the political authorities, many honorable members of the Society and students. The special ceremony will include a roundtable discussion on "*Research in Physics a hundred years ago and today*" and a plenary talk by Theodor Hänsch - Nobel Laureate 2005- on the "*Visions for Physics*". During the afternoon outreach activities and exhibits will be proposed to the public.

*(Extracts from an upcoming EPN-Article, written by Alessandra Hool and Christophe Rossel)*

## Progress in Physics (3)

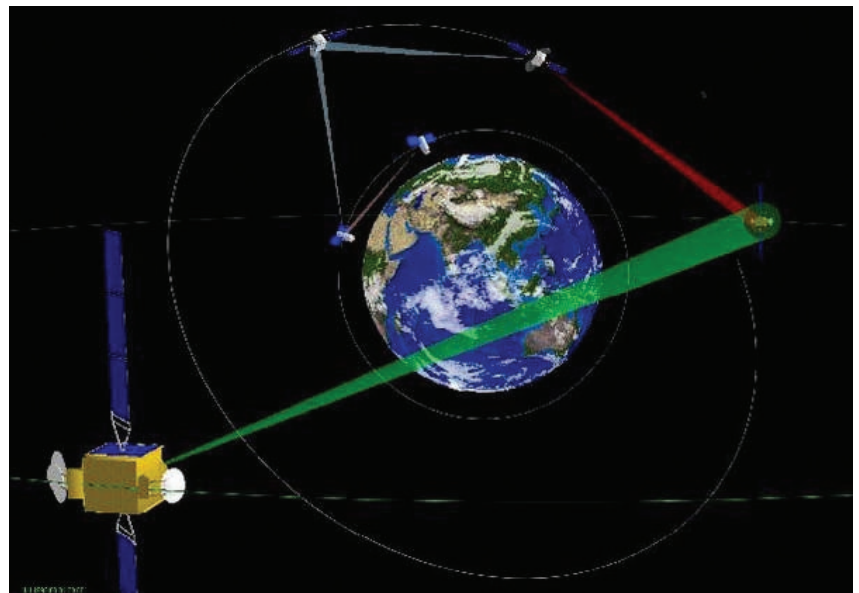
### Optical Terminals for Data Communication in Space

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In our series "Progress in Physics" we present research topics from Swiss physical institutes, but also engineering highlights from Swiss industries, performed by physicists. The following article describes an industrial space project, the manufacturing of Optical Terminals for fast data exchange within satellite networks, using laser beams. The terminals must generate optical links between fast orbiting satellites over large distances of up to 60'000 km with sub-arcsec pointing accuracy. These challenging link requirements need solutions at the limits of current technologies. The terminals are designed and manufactured in Switzerland, and the whole business is rapidly growing. We describe in the following, how to achieve the stringent technical performance of such masterpieces.

#### System Layout

The increasing demand for high speed Internet data transfer over large distances will doubtless be dominated by optical technologies, using fiber and optical free space connections. One expects about 10% of the Internet traffic being transmitted in future via satellite networks. After the worldwide communication crisis in the early nineties a critical review of all technologies involved has started. New applications like the transfer of large 3D images in real time will need very powerful point-to-point and point-to-multi-point communication channels, focussing on satellite to satellite, but also on satellite to ground station communication links. Thereby laser beams transfer data information over distances of up to 60'000 km between satellites at different orbits (Fig. 1).



*Fig. 1: Network of satellites with Optical Terminals for bi-directional data transfer. Low earth orbiting satellites interact with higher orbiting satellites and ground stations. The accurate mutual pointing of the laser beams from terminal to terminal is the main technical challenge.*

The free space data exchange by optical means requires at both link ends optical transceivers, so called "Optical Terminals". The sender terminal emits the information towards the counter station, where this forward data stream beam is either intensity or phase modulated. In the reverse direction the terminal receives simultaneously the very weak backward data signals from the counter station.

The primary advantage of a free space laser link is its narrow beam width. If the laser wavefront is diffraction limited, the beam divergence angle  $\delta\alpha$  is proportional to  $\lambda/D$ , where  $\lambda$  is the wavelength and  $D$  the diameter of the transmitter aperture. Taking e.g.  $\lambda = 1.064 \mu\text{m}$  (Nd-Yag Laser) and  $D = 135 \text{ mm}$  results in  $\delta\alpha \sim 1 \text{ arcsec}$ . Such a small divergence causes a high 'antenna gain', since the emitted intensity can be kept within a diameter of only several 100 m at the counter terminal, 60'000 km away. This leads to a much better signal to noise ratio, compared to competing Radio Frequency (RF) links, and allows a faster data transmission at the same bit error rate. However, the narrow beam width causes also the main technical challenge for optical communication systems in space. The receiver must acquire the slender transmit beam and the optical connection must be maintained with subarcsec accuracy throughout communication.

The requirements for a space terminal are *low mass, compact packaging size and rigidity* against space environmental loads (launch vibrations, separation shock, zero gravity operation, thermal gradients, and severe radiation impacts). We chose a layout (Fig. 2), which main part is an all-mirror, afocal telescope of 10x magnification, often called an "Optical Antenna". The telescope should enlarge the diameter of the laser beam by a factor 10 to obtain the small beam divergence  $\delta\alpha$  mentioned above. The received radiation is directed in opposite direction through the telescope to a point sensor for fast data demodulation.

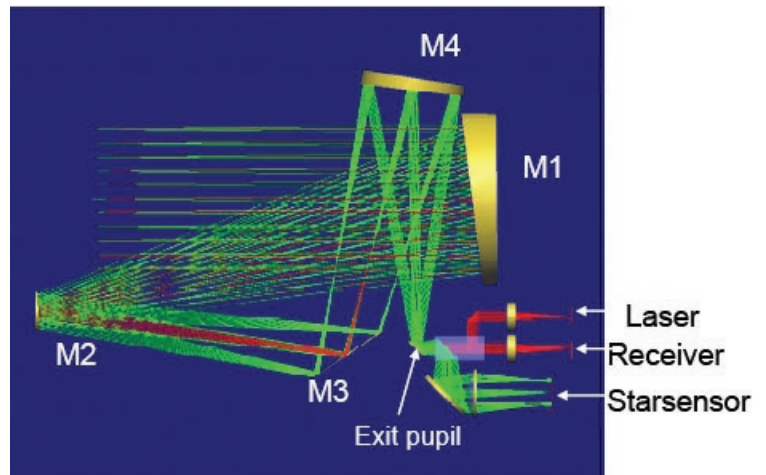


Fig. 2: Optical Terminal with an all-mirror, afocal telescope of 10x magnification. In the exit pupil is a fast scanning mirror to fine adjust the laser beam to the counter station.

The chosen arrangement of four folded mirrors M1...M4 is that of a *Kepler telescope*, where M1 and M2 act as 'objective lens' and M4 has the function of the 'ocular lens'. The mirror M3 is only a plane folding mirror. We see in the exit pupil of the telescope a 'fine pointing device', which is a fast scanning mirror, to deflect the laser beam about  $\pm 10^\circ$  in both directions. This leads, due to the 10x telescope magnification, to a beam sweep of  $\pm 1^\circ$  on M1 at the space side. This controllable beam steering is needed to keep the laser beam direction stable, since satellite platforms are rather instable and jittering.

To reduce the manufacturing complexity, the mirror surface functions are only *conical aspheres*: M1 and M4 are parabolic and M2 is hyperbolic. All mirrors are made of Zerodur, a glass ceramic of zero thermal expansion, known as preferred material for the large ground based telescopes in astronomy.

To achieve the specified high antenna gain, any central obscuration of the laser beam must be strictly avoided, not to broaden the beam spot at the counter terminal by diffraction at the obscu-

ration. This forced us to design M1, M2 and M4 as 'off-axis' aspheres, i.e. mirror segments, cut out from rotational symmetric 'mother' mirrors.

We also note at the short side a 2D star-sensor, which permanently monitors the star pattern inside the field of view of the telescope, and compares it with pre-programmed star configurations. One obtains so the absolute angular orientation of the terminal in the orbit, which is an important information when switching the link from one satellite to another. In Fig. 3 we see an Optical Terminal, based on the described layout and optimized for mid range data links, a product of Oerlikon Space AG.

### System Improvement

The question was raised, how to further improve the wavefront flatness of the laser beam and thus the antenna gain, but without increasing the available space and keeping mirrors M1, M2 and M4 conical?

One elegant possibility would be to polish some 'freeform' surface deformations on M3, i.e. changing it from a plane to a structured mirror, called a *reflective hologram*. Since M3 is near to the entry pupil at M1, but also near to the intermediate image between M3 and M4, this surface manipulation should correct both, the spherical aberration and the field distortion, an important quantity for the star sensor.

Our design work shows that the wavefront quality can be improved by a factor 2. The polishing of the surface correction on M3 could be done by modern CNC technologies [1].

In conclusion, we showed that optical space terminals are rather complex devices to establish the data transmission over large distance between fast moving and mechanically jittering space platforms. To assure the high reliability under the severe space environmental conditions, a deep physical understanding of all parameters involved has to be part of the engineering work.

### References

[1] "Advanced Optics using Aspherical Elements", Editors: B. Braunecker, R. Hentschel, H.J. Tiziani, SPIE Press Book (2007), ISBN 978-0-8194-6749-2

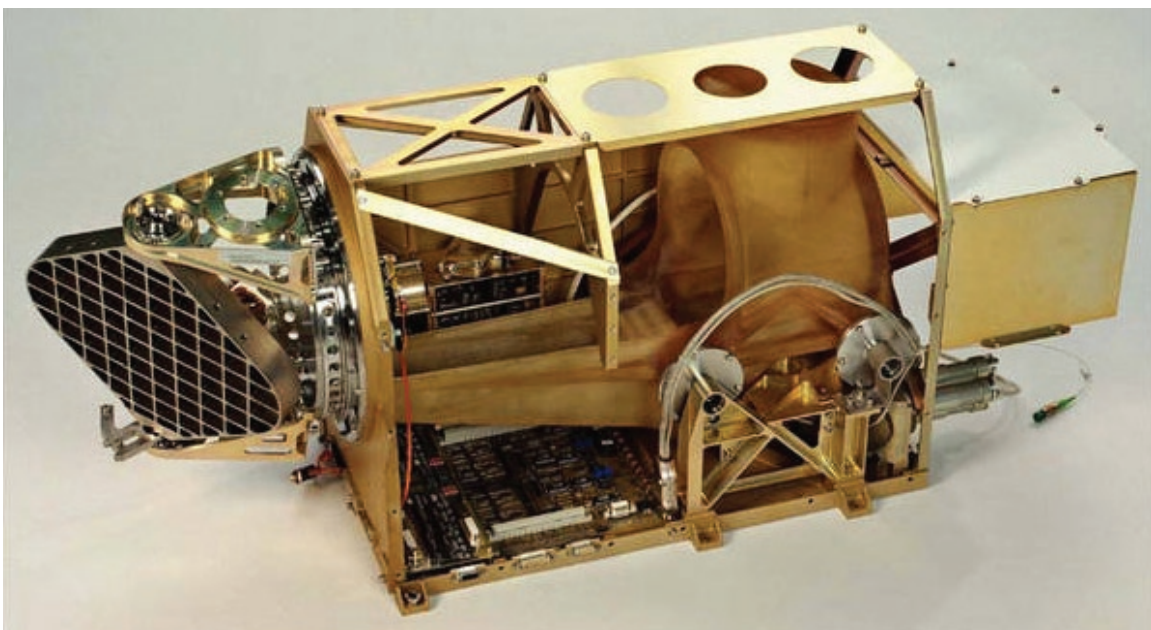


Fig. 3: Optical Terminal from Oerlikon Space AG. The large mirror left in front is a 'coarse pointing unit' to direct the laser beam to different counter stations without changing the orientation of the satellite.

## Progress in Physics (4)

### Mirror Matter – Experimental Search for Neutron to Mirror Neutron Oscillations

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The idea of a mirror world consisting of mirror particles – even mirror planets and mirror stars – has inspired many fantasies and works of fiction. However, the roots of this idea are standing on a solid particle physical model, which goes back to 1956 and the work of Lee and Yang [1] on the possible violation of mirror symmetry (also called parity) and its discovery only a year later by Wu et al [2] and Garwin et al [3]. This violation is manifest in the weak force, which interacts only with left-handed particles but cannot couple to right-handed ones. Already then, Lee and Yang proposed the concept of introducing mirror particles with right-handed interaction. In this broader sense, the breaking of mirror symmetry could be restored.

As each of the two worlds has its own force mediating particles for the electromagnetic, strong and weak interaction, the only way for any interplay is due to gravity. Actually it turns out that mirror matter is a viable candidate for the explanation of the Dark Matter puzzle. Apart from gravitational interactions, subtle effects could lead to oscillations between neutral particles from the two worlds such as photon to mirror photon, neutrino to mirror neutrino or neutron to mirror neutron. Experimentally investigated are the possibility of photon to mirror photon oscillations by a dedicated effort [4] and neutrino to mirror neutrino by many neutrino-oscillation searches. Recently neutron to mirror neutron oscillations received a lot of interest, as they could possibly also provide a mechanism for cosmic rays to arrive at the earth with highest energies [5].

On a very short time scale, two experiments have been performed at the Institut Laue-Langevin (Grenoble, France) to search for such oscillations and to set a lower limit on the oscillation time  $\tau_{nn'}$  in the case of its nonobservation. These measurements used their respective apparatus built for a Neutron Electric Dipole Moment experiment. The neutrons, that one uses, are so called ultra cold neutrons (UCNs). The kinetic energy of UCNs is so low (in the order of 100 neV, corresponding to mK - hence the name) that they are totally reflected by certain materials and can therefore be stored for hundreds of seconds. The experimental principle requires a measurement under two different conditions. In both, one fills UCNs into the storage chamber, stores them for a given time and counts afterwards the remaining UCNs in a detector. In one case however, one applies a moderate magnetic field (a few  $\mu\text{T}$ ) over the storage chamber. In the other case, the 4 layer magnetic shield is demagnetised and the magnetic field generating coil switched off, thus effectively creating a zero field region (in the order of 10 nT) at the storage chamber.

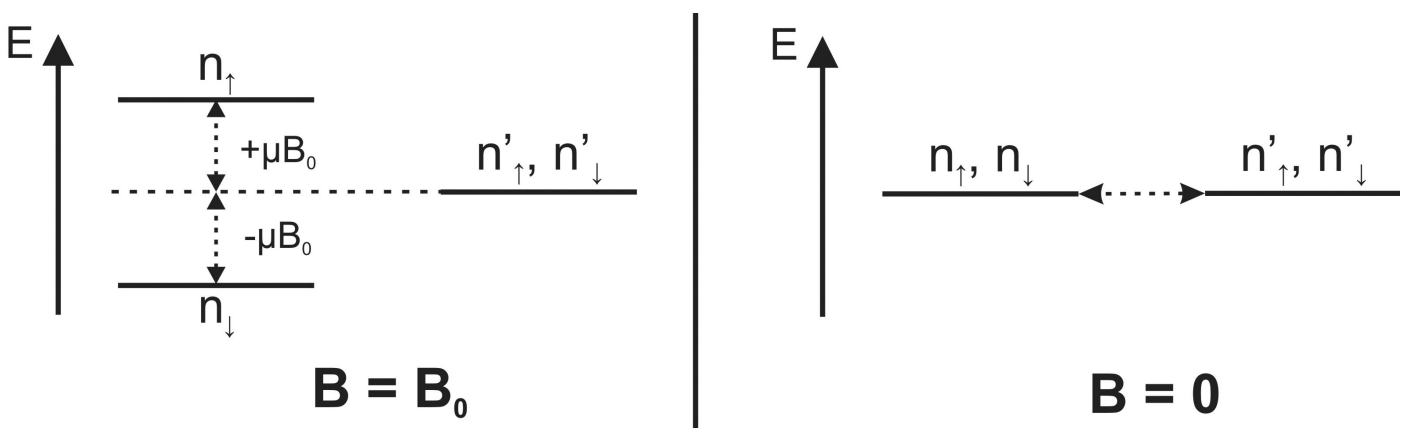


Figure 1: Energy scheme for the two cases field on ( $B = B_0$ ) and field off ( $B = 0$ ).  $n_{\uparrow}$  and  $n_{\downarrow}$  denote the spin-up and spin-down neutrons and  $n'_{\uparrow}$  and  $n'_{\downarrow}$  the corresponding mirror neutrons.

The neutron couples to the magnetic field  $\mathbf{B}$  due to its magnetic moment  $\mu$ , thereby changing its energy by  $\pm\mu B$ . The mirror neutron cannot couple to the ordinary magnetic field and it is assumed that no mirror magnetic field is present at the site of the experiment. In the case of an applied field over the storage chamber, the oscillation from neutron to mirror neutron is suppressed due to the separation of their energy levels, whereas in the zero field setting the oscillation can take place (see Fig. 1). The relevant time scale for the oscillation to happen is the free flight time  $t_f$  of the UCNs between wall collisions as every wall collision probes whether an oscillation has taken place. If such oscillations occurred the mirror neutrons would leave the storage chamber resulting in a decreased UCN count at the end of the storage time. Due to the fact that many wall collisions take place during storage, it is possible to search for oscillation times  $\tau_{nn'}$  much larger than  $t_f$ .

In the analysis, one calculates the ratio of average counts for field off and field on. Any reduction of this ratio below one could be an indication of neutron to mirror neutron oscillations. No deviation from one within the error had been observed in the two experiments. The first experiment set a lower limit on the oscillation time at 95% confidence level (C.L.) of

$$\tau_{nn'} > 103 \text{ s (95\% C.L.) [6]}$$

Only a few weeks later, the second experiment reported a limit at 90% C.L. of

$$\tau_{nn'} > 414 \text{ s (90\% C.L.) [7]}$$

using a 10 times larger storage chamber. The use of a more powerful UCN source (such as being constructed at the Paul Scherrer Institut (Villigen, Switzerland) [8]) combined with a large storage chamber would allow for measurements in the order of  $10^3$  s. A dedicated effort and the construction of a new apparatus is required to reach  $10^4$  s.

#### References

- [1] T. D. Lee and C. N. Yang. Phys. Rev. 104, no. 1, 254 (1956).
- [2] C. S. Wu et al. Phys. Rev. 105, no. 4, 1413 (1957).
- [3] R. L. Garwin, L. M. Lederman and M. Weinrich. Phys. Rev. 105, no. 4, 1415 (1957).
- [4] A. Badertscher et al. Phys. Rev. D 75, 032004 (2007).
- [5] Z. Berezhiani and L. Bento. Phys. Rev. Lett. 96, 081801 (2006).
- [6] G. Ban et al. Phys. Rev. Lett. 99, 161603 (2007).
- [7] A. P. Serebrov et al. arXiv 0706.3600 (2007).
- [8] [ucn.web.psi.ch](http://ucn.web.psi.ch).

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## European Physical Society (EPS) Plasma Physics Division Ph.D. Award

The European Physical Society (EPS) Plasma Physics Division announces its PhD Research Award 2008. Up to three prizes will be awarded to recognise exceptional quality of the work carried out by young physicists as part of their PhD research in any area of plasma physics. More information, including instructions for nominations, can be obtained at

<http://plasma.ciemat.es/awards.shtml>

The deadline for nominating a candidate for the 2008 awards is 15th February 2008. Self-nominations will not be accepted.

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