SCK•CEN
THE BELGIAN NUCLEAR RESEARCH CENTRE

MATERIALS FOR SPACEBORNE LASER SYSTEMS

Background

Advanced laser systems are attracting a growing interest for space missions, in particular for LIDAR (LIght Detection And Ranging) applications. An important issue for the LIDARs is the very strict requirements on the optical performance and more specifically the need for a high optical output power combined with a nearly perfect output beam quality. These features are traditionally in conflict with each other. Thermally induced phase distortions indeed corrupt the beam quality of high-power solid-state lasers and it becomes increasingly difficult to maintain a good beam quality while increasing the output power. A possible solution of the problem is to use the optical phase conjugation, which provides a method to dynamically correct for those aberrations.

A process by which phase-conjugated waves can be generated is the SBS (stimulated Brillouin scattering). SBS mirrors commonly used in terrestrial application are based on liquids or gases, which are not "space-friendly" and often toxic. The solid-state alternative seems the most appropriate for space. Such PCMs (Phase-Conjugating Mirrors) have been the subject of many research efforts in recent years and a significant progress in improving their characteristics has been achieved. However, the issue of space qualification remains open. To address it, the European Space Agency initiated in 2004 the research project named "Solid-State Phase Conjugation, Radiation Testing and Evaluation for Core Laser Technologies" with the TRT (Thales Research & Technology), France, as the prime contractor, and the CSL (Centre Spatial de Liège) and SCK·CEN as the subcontractors. The project is to be completed in 2006.

Objectives

To qualify a PCM for a spaceborne laser system, one has to address a number of specific issues. Such a component must be mechanically rugged to sustain vibrations during the launch phase, provide a low out-gassing to prevent optical surfaces contamination in vacuum, be highly reliable to operate properly without interventions during prolonged mission times. In addition, the presence of radiation in space means that it must be radiation tolerant.

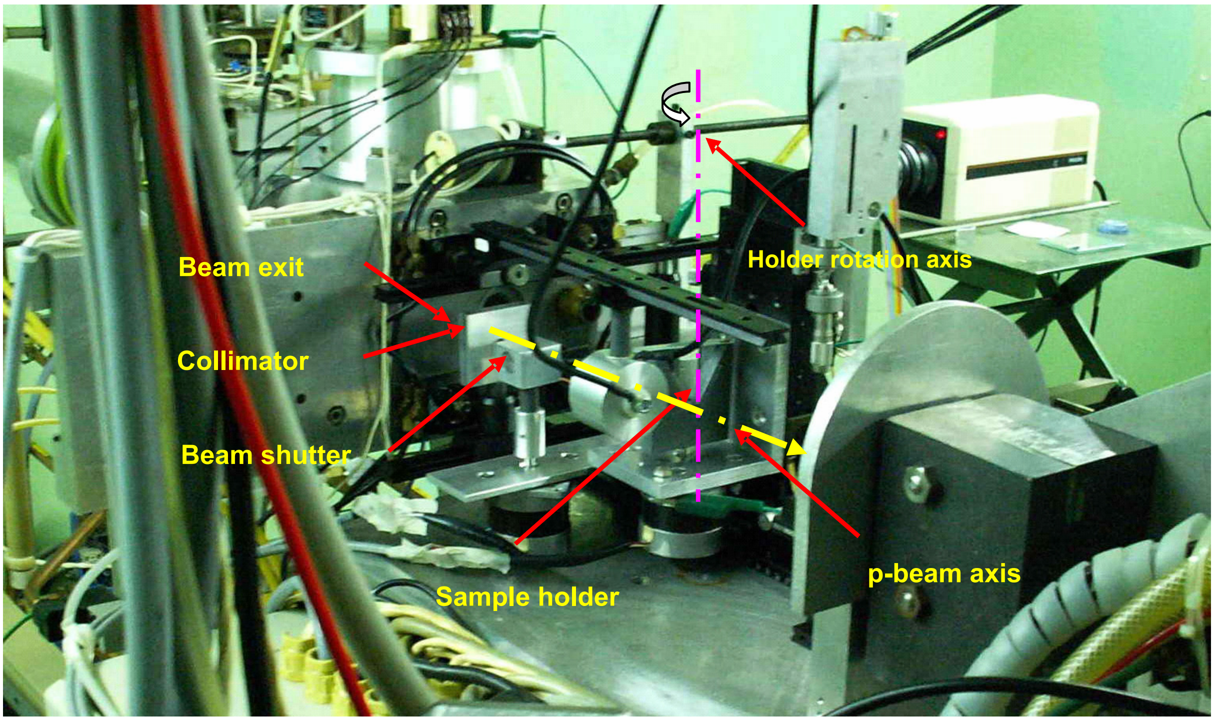
Our objective was to define the list of candidate PCM materials, which can sustain the space radiation conditions, to perform radiation testing of the selected materials and components, and draw conclusion about the sensitivity of the tested materials to radiation.

Principal results

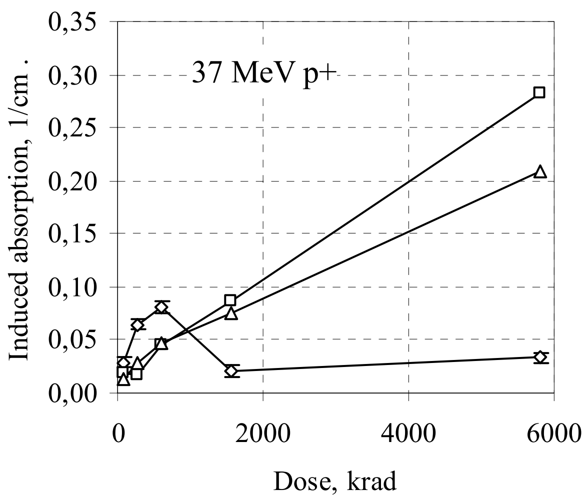
Several effects can contribute to the radiation-induced performance degradation of the PCMs. Based on the data available in the literature, we concluded that the radiation-induced optical transmission degradation (coloration of glasses) may have the strongest impact on the performance. Fused silica (SiO_2) and telluride oxide (TeO_2) have been identified as suitable radiation-tolerant materials and tested under gamma and proton radiation. SCK•CEN performed gamma-irradiation in the RITA facility. For the proton radiation tests, the cyclotrons of the VUB (Vrije Universiteit Brussel) and of the Paul Scherrer Institute (PSI) in Switzerland have been used. At the VUB a dedicated set-up was designed and built to allow for in-air irradiation (previously irradiations were performed under vacuum).

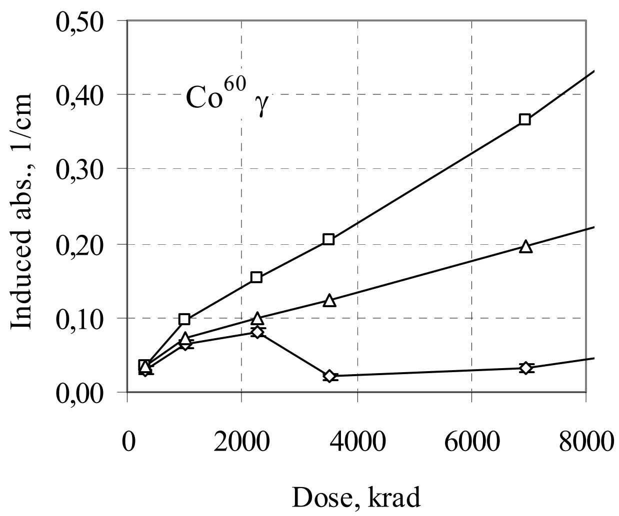
The radiation tests showed that at a dose level ~1 Mrad (10 kGy), which is often considered as the figure of merit for space applications, the induced optical absorption at the working wavelength is indeed very low, i.e. below 0.02 and 0.002 cm^{-1} for silica and TeO_2, respectively. In a standard optical system such levels would not create any problem. However, theoretical estimations indicate that for a SiO_2 based PCM the thermally induced self-focusing may play a role even at absorption levels of ~0.001 cm^{-1}. Therefore, to complete the qualification, actual PCMs have been irradiated and the impact of radiation will be assessed by checking the performance of the laser system operating with the irradiated components. That will be done in January-February 2006 by the TRT.

In addition to the transmission measurements at the working wavelength, the optical properties of radiation induced colour centres in the UV were investigated with the intention to derive a correlation between proton and gamma radiation. There are contradictive opinions in literature whether the effects produced by two types of radiation can be scaled to one another. Our results show that for both types of radiation the induced absorption is dominated by the same types of radiation defects, generated with a comparable efficiency.



Proton-irradiation set-up at the VUB





Variation of the 216-nm absorption band amplitude with radiation dose increase for different types of silica. Diamonds – Lithosil, squares – SU1, triangles- SU311.

For example, the amplitude of the 216-nm absorption band for three different types of silica (Lithosil, SU1 and SU311) as a function of the radiation dose for 37 MeV protons with a dose-rate of 100 kGy/h (left hand side graph) is similar to that observed under Co^{60} gamma-radiation with a much lower dose-rate of 300 Gy/h (right hand side graph). The differences observed between the graphs can be explained by taking into account the differences in the dose-rates.

Future work

Spectroscopic measurements on the irradiated silica samples will be continued to address the effect of long-term post-radiation relaxation.

Main contact person

Andrei Gusarov, andrei.goussarov@sckcen.be

Main reference

A. Gusarov, Technical Note 4: Irradiation campaign (WP1400), Restricted Contract Report, SCK•CEN-R-4261, October 2005, 20p.