# LIDT TESTS ON OPTICAL ELEMENTS UNDER SPECIAL CONDITIONS

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**Abstract**: This contribution presents a technology for the design, deposition and testing of thin film coatings on optical elements designed to operate in high power pulsed laser systems. I have designed and built a test station which is used as an addition to the thin film coating production facilities used at the Institute of Scientific Instruments.

**Keywords**: LIDT, coatings, e-beam evaporation

## 1 INTRODUCTION

Laser induced damage threshold (LIDT) is an important parameter when considering high power laser systems. Such system which operate at laser energies high enough to damage an optical element already appeared in the 1970s [1]. The development in this field still continues with laser facilities reaching very high laser pulse energy levels. A few examples from recent years include ELI Beamlines or the HiLASE project, which features a kilowatt average power 100 J-level diode pumped solid state laser [2]. Various optical components are a key part of such setups and therefore a great care must be taken when designing and using them.

The design and manufacturing of thin film coatings has a long lasting tradition at the Institute of Scientific Instruments. We currently operate two electron beam (e-beam) coating systems. The first one is BAK550 by Balzers which has recently been refurbished and the second one is SYRUSpro 710 by Bühler (formerly Leybold Optics), which is equipped with the APSpro plasma source. This system is therefore capable of plasma ion assisted deposition (PIAD). As the need to evaluate laser induced damage threshold of coatings produced at our institute arose in the past, we have started to look into this area as it is a valuable addition to our existing coating production capabilities. The aim of my work in this area is to be able to test optical components for LIDT both produced at our institute and at other facilities.

One of the important features of the LIDT test station is the ability to test optical components under special conditions such as low temperatures. This is important, because high power laser require a cooling of some of the optical components such as solid state laser amplifiers to the temperatures of either helium vapors or liquid nitrogen and the optical properties of both thin film coatings and the substrates they are on are temperature dependent [3].

## 2 OPTICAL COATINGS

Optical coatings can serve as a variety of optical filters. My work will in the first stage concentrate mainly on antireflective (AR) and highly reflective (HR) coatings as they have a simple design, are easy to produce and are widely used in laser systems to minimize optical losses. This applies especially in cases of laser amplifiers where the one side needs to be AR coated and the other needs to be HR coated. The beam will pass through these amplifiers multiple times and efficiency is a key issue. Both our coating systems will be used to produce optical coatings for testing, as there are differences in LIDT depending on the technology used as they have a different microstructure [4]. The choice of coating materials is also critical. One of the materials known to perform well with respect to LIDT is $HfO_2$ [5]. Other suitable candidates for comparison include $TiO_2$, $Ta_2O_5$ or $SiO_2$. The aim of this work is to evaluate LIDT in case of AR and HR coatings consisting of different coating materials and produced using different deposition methods both at room temperature and cryogenic temperature.

## 3 LIDT TEST STATION

### 3.1 LASER SOURCE

As the test source we use Brilliant b by Quantel. It is a Nd:YAG pulsed laser operating at a base wavelength of 1064nm. By adding 2ω, 3ω and 4ω modules, 532nm, 355nm and 266nm wavelengths can be produced. Currently only the base wavelength is used. The source laser parameters are summed up in the following table. The laser is operated at or close to the maximum pulse energy value as this way the best stability of the laser is ensured. The pulse energy is measured by a Fieldmax II energy meter by Coherent.

| Parameter | Value |
|---|---|
| Repetition rate | 10 Hz (or single shot) |
| Pulse length | 6 ns |
| Pulse energy | max. 850 mJ @ 1064 nm |

**Table 1:** Laser parameters.

### 3.2 VACUUM CHAMBER

The vacuum chamber is necessary for the cryogenic temperature tests. The sample needs to be protected from condensation of water vapors etc. which occurs when it is cooled down under atmospheric pressure. The diameter of the chamber is 260 mm and it is fitted with ISO-K and ISO-KF flanges that allow for pumping, placing a sample holder and the use of optical windows. The working pressure is in the order of $10^{-5}$ mbar. The sample is cooled by a cold finger which extends out of the chamber. For simplicity liquid nitrogen cooling is used at this stage and the temperature of the sample is monitored by a Pt probe. The sample holder allows for angles of incidence between 0° and 60°. The chamber is pumped by a turbomolecular pump.

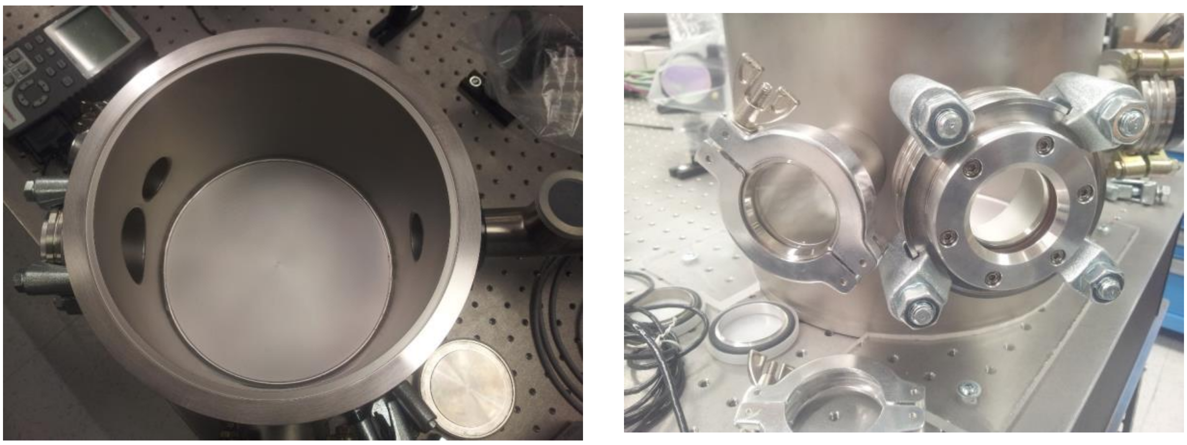

**Figure 2:** Vacuum chamber

## 4 EXPERIMENTAL SETUP

The following experimental setup is used:

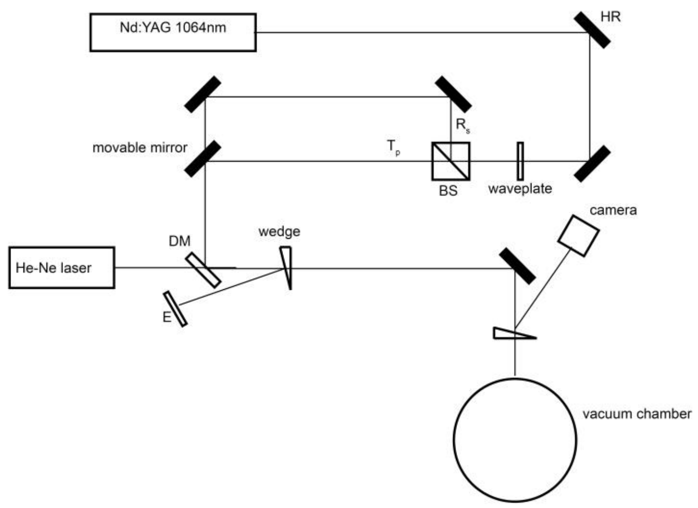


**Figure 1:** Experimental setup: HR – mirror, $T_p$, $R_s$ – transmitted, resp. reflected polarization, BS – polarizing beam splitter, DM – dichroic mirror, E – energy meter

The source laser pulse is propagated through a telescope to increase the spot size to approx. 20 mm. This is done to avoid accidental damage to optical components along the pulse path. The pulse then goes through a variable attenuator consisting of a wave plate and a polarizing beam-splitter. Depending on the polarization state the pulse follows one of the paths available to it. A movable mirror is used to switch between polarizations without the need of moving any other optical elements. Two quartz wedges are used to direct a portion of the pulse energy to an energy meter and a camera. The camera is used to inspect the spatial profile of the pulse. At the end of the optical path, the pulse is focused to a spot size of approx. 0.5 mm and hits a sample placed in a vacuum chamber. Another low power visible laser beam is used as a probe beam to ensure the source laser pulse hits the desired test site and also for damage detection based on light scattering which increases as damage occurs at the test site.

The LIDT test station will be operated in the so called 1 on 1 regime where the measurement method is the following. After the sample surface has been cleaned and inspected by a microscope, the sample is placed into the vacuum chamber. The chamber is evacuated and the sample is illuminated by the test laser. The damage threshold value is obtained by the damage-probability method. At least ten test sites on the sample are exposed to one pulse energy and the fraction of damaged sites is recorded. This procedure is then repeated for other pulse energies to for a plot of damage probability versus pulse energy. Linear extrapolation of the damage probability data to zero damage probability yields the threshold energy. This procedure is thoroughly described in [6]

## 5 CONCLUSION

I have designed a LIDT test station which is capable of testing optical coatings on various optical elements. It has been assembled and will be put into preliminary operation in the very near future. The station can be used for test under special conditions, mainly cryogenic temperatures. It serves as a valuable addition to our existing well established optical coating capabilities and opens new areas of research in the field of thin film optical coatings.

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