Development of High Damage Threshold and Ultra-low Loss Mirrors

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Recent rapid progresses on high-power laser require "high damage threshold" and "ultra-low loss" mirrors for gravitational-wave detectors and various laser experiments. There is no such mirror of which satisfy both of requirements with the highest levels.

To realize it, coating qualities are being investigated in collaboration with SIGMAKOKI CO., LTD. As a result, we succeed to make the high-reflectivity mirror of 99.99% [1]. It has scattering loss of less than 10 ppm as already described in the previous annual report. In addition, it has a damage threshold of 446 J/cm^2 for 10 ns pulse lasers. The loss of less than 10 ppm is the highest level in the world and the damage threshold is the best value in Japan as far as we known.

At research hub for advanced nano characterization in the University of Tokyo, we took photos of film cross-section by Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) and made X-ray Photoelectron Spectroscopy to evaluate not only elemental compositions but also binding energies of each film contents. Figure 1 shows a cross-section of the film. Uniform and dense films are formed. Furthermore, the film boundaries are also clear and flat.

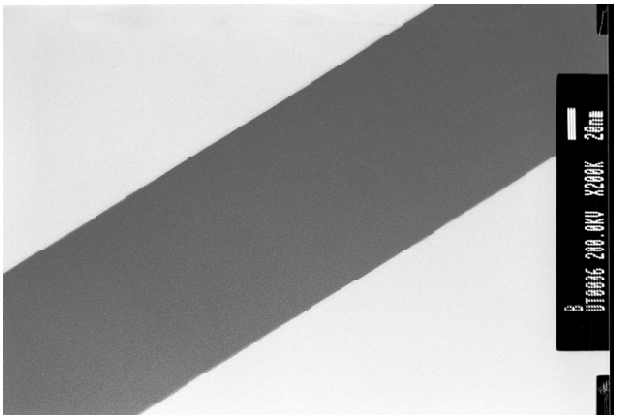

Figure 1: A film cross-section taken by a Transmission Electron Microscope (TEM).

At the University of electro-communications, an ellipsometer system with high-power CO^2 laser irradiation was set up to catch the premonitory phenomenon and to reveal the mechanism of break-down process of the film.

The above knowledgewere fed-back to the coating process. The temperature control improvements and residual gas reductions were performed step by step. As a consequence of such steady progresses, we obtain the higher-quality mirror than that of the start.

This high quality mirrors are also valuable for KEK quantum beam experiment. In the KEK facility, an inverse Compton scattering process between accelerated electron and low-energy laser light make a hard X-ray beam. To increase the X-ray luminosity, high power (low-energy) pulse laser and its accumulation optical cavity are needed. Development of the cavity is a collaborative work with KEK.

As a part of the activity, our developed mirror was tested by Institute for Laser Technology to evaluate its damage threshold. The measuring conditions are as follows. The beam has a wavelength of 1064 nm, a pulse width of 10 ns and its cross-section of 380 μm × 415 μm, respectively. Incident angle to the mirror is 0 degree. The "1-on-1" evaluation method was chosen. Total 23 shots were flushed in the power density range of 220–470 J/cm^2. We obtained a damage threshold of 446 J/cm^2. It corresponds to 44.6 GW/cm^2 for continuous-wave laser. This measured value is the best among the database of the Institute for Laser Technology. Because the past best is 300 J/cm^2 [2], we succeed to enhance the threshold by a factor of 1.5.

Our developed mirrors were delivered to the KAGRA project for its pre-mode cleaner optical cavity as shown in Fig. 2. It is a milestone of KAGRA mirror evaluation group in NAOJ.

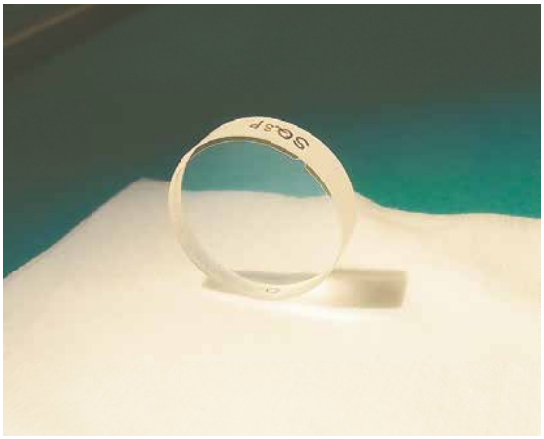

Figure 1: KAGRA mirror for a pre-mode cleaner cavity.

Finally, we express the great appreciation for SIGMAKOKI's staffs.

References

[1] TATSUMI, D., UEDA, A., YONEDA, H., a talk at Japan Physical Society, 2014 Spring, 27pTL-1.
[2] Database on high-power tolerance of optics, http://www.ilt.or.jp/engindex.html