Long Term Tests of Resonator Optics in ArF Excimer Lasers

Nils Beermann[c 1], Holger Blaschke[c], Henrik Ehlers[c], Detlev Ristau[c], Dirk Wulff-Molder[b], Sigrid Jukresch[a], Ansgar Matern[a], Claus F. Strowitzki[a], Andreas Görtler[a], Martin Bischoff[d], Dieter Gäbler[d] and Norbert Kaiser[d]

[a] Coherent GmbH, Zielstattstrasse 32, 81379 Munich, Germany
[b] Korth Kristalle GmbH, Am Jägersberg 3, 24161 Altenholz, Germany
[c] Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany
[d] Fraunhofer IOF, Albert-Einstein-Strasse 7, 07745 Jena, Germany

Aim of the work is the optimization of the resonator optics of excimer laser systems to achieve longer lifetimes and reduced costs of ownership. Under high photon fluxes (typically 80 mJ / cm²) long-term tests of the resonator optics has been done in an ArF-excimer laser at 193 nm wavelength. Especially the degradation of the partially reflecting out coupling mirror used as internal resonator has been investigated. The contamination and damage of the optics surfaces were analyzed. New special coatings have been successfully tested.

The work was done during an ongoing national joint project including excimer laser user and optical coating and optics manufacturer for the VUV.

With a experimental excimer laser long-term tests of the resonator optics has been done. The laser energy was stabilized to 28 mJ, corresponding to a photon flux of 80 mJ / cm². The repetition rate was 1 kHz in continuous operation; the pulse length was 12 ns (FWHM). An electrostatic dust removing system has been integrated into the laser chamber. The resonator optics also acts as gas sealing device for the laser chamber (= internal resonator). The inner surface of the resonator optics is in contact with the laser gas mixture (including fluorine). The beam path from the out coupling mirror of the laser to the power meter and energy meter was realized with a stainless steel rod and sealed to laser and metrology tools. It was purged with pure nitrogen, additionally cleaned with special filters to reduce contaminations. The laser was controlled by a computer. The output power and the pulse energy were recorded by the controlling computer system, too.

In some test series optics has been tested that were manufactured by different coating suppliers using “state-of-the-art” technology. The substrates were CaF_2 in 193 nm quality from one vendor. The specification for the out-coupling optics was identical for all probes, but the coating was manufactured by the different suppliers. On each test optic 250 million pulses have been accumulated. Then the optic degradation was analyzed. The optical performance (reflection, transmission etc.) was measured before and after the test. Analysis of the contamination on the laser gas site of the optic was done with XPS and similar methods. The electrode material and other metals – used in the laser chamber – were detected. On the exterior side of the optics degradation of the surface was observed, too. Here a roughening of the surface in the irradiated area was detected which led to higher stray light. As a result the transmission of the laser light is reduced and the output energy no longer be guaranteed. A new optic has to be installed. An analysis showed growth of $CaCO_3$ and organic compounds. Based on these data a first model for these damage phenomena was investigated. Further tests are in preparation to get more information. With special coatings on the exterior side of the optics these damage phenomena can be avoided. This was proved by tests under the same conditions (80 mJ / cm² @ 1 kHz) over 1 billion pulses.

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[1] E-mail: n.beermann@lzh.de