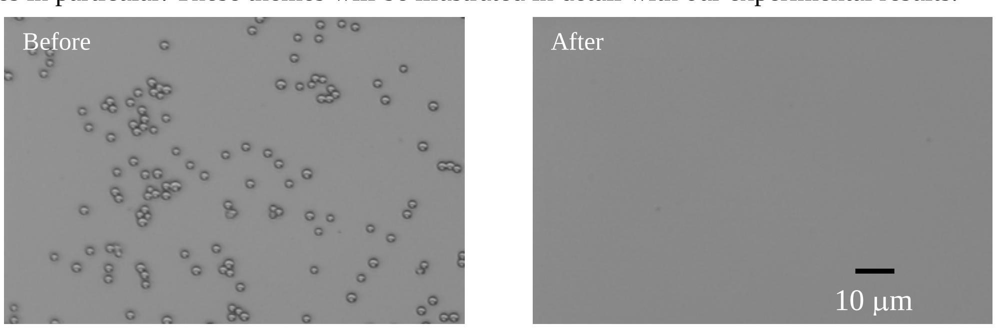
LASER CLEANING OF PARTICLES FROM OPTICAL MATERIALS – A RICH TEST SYSTEM FOR LASER/PARTICLE/MATERIAL INTERACTIONS

D M Kane[1], A J Fernandes, A Joyce and S Pleasants[2]
Department of Physics, Macquarie University ~ Sydney, NSW 2109, Australia

B Luk'yanchuk
Data Storage Institute; Agency of Science, Technology and Research; Singapore 117608

N Arnold
Angewandte Physik, J. Kepler University, Altenbergerstrasse 69, A-4040 Linz, Austria

As the footprint of optical components in photonic (and related) devices decreases to millimetres and less, and the size scale of fabricated, machined and/or etched features within these glass and plastic components enters the sub micron range required for functionality at near infra-red and visible wavelengths, there is a growing need to develop "dry", non-contact, surface cleaning techniques for this material group, to augment current wet and plasma cleaning techniques. We have been studying dry (and "damp") laser cleaning using nanosecond-pulsed lasers to clean small-particle (micron and sub-micron) and hydrocarbon contaminants from glass and plastic materials. Particle contaminants prove to be far more easily removed from highly transparent glass substrates than predictions, using the most highly developed laser cleaning theory available to date, based on van der Waals adhesion and the absorption coefficients of the bulk materials from which the particles are made, would suggest [1,2]. Dry laser cleaning proves to be a viable technique for cleaning micron and sub-micron particles from glass and optical materials in many instances ([1-4], fig. below shows result of removing spherical silica particles from a fused silica substrate with a single 195 mJ/cm^2 KrF laser pulse). This is in contrast with the parallel results [5] achieved in laser cleaning studies for removing silica and polystyrene particles, as small as 65 nanometres in diameter, from silicon wafers. The experimental results from silicon lead to the conclusion that optical-damage-free, dry laser cleaning is not possible when van der Waals adhesion on atomically smooth substrates and strong substrate absorption are the dominant factors. Theory based on this is consistent with experimental results for the silicon material system. In contrast, any optical materials system leads to a range of possible outcomes depending on the nature of adhesion (electrostatic repulsion can become important), the surface roughness/polish and differences in the optical properties of small particles compared with those of the bulk material (as established in our experiments). Surface acoustic waves also become an important physical mechanism for effecting detachment. Laser cleaning experiments become a significant test method for interrogating the range and dependencies of interactions of laser radiation with particles on surfaces and for elucidating the materials properties of small particles, a topic of much interest for nano-particles in particular. These themes will be illustrated in detail with our experimental results.



1. Acoustic substrate expansion in modeling dry laser cleaning of low absorbing substrates, S. Pleasants, N. Arnold and D M Kane, Appl. Phys A **79, #**3, 507-514, (2004).
2. Modelling laser cleaning of low-absorbing substrates: the effect of near field focussing, S Pleasants, B S Luk'yanchuk and D M Kane, Appl. Phys. A **79**, #4-5, 1595- 1598 , (2004).
3. D.M. Kane, A.J. Fernandes and D.R. Halfpenny, Pulsed laser cleaning of particles from surfaces and optical materials, ch. 4, Laser Cleaning, Ed.: B.S. Luk'yanchuk,World Scientific (Singapore, 2002).
4. Enhanced laser cleaning via direct line beam irradiation, A. J. Fernandes and D. M. Kane, Appl. Phys. A **79, #4-5**, 735- 738 (2004).
5. Laser Cleaning, Ed.: B.S. Luk'yanchuk,World Scientific (Singapore, 2002).

[1]Presenting author: Prof. Deb Kane, debkane@physics.mq.edu.au
[2] Now at Dept. of Information & Image Science, Chiba University, Tokyo, Japan