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Ion Beam Figuring Solution for High Performance Diamond Optics

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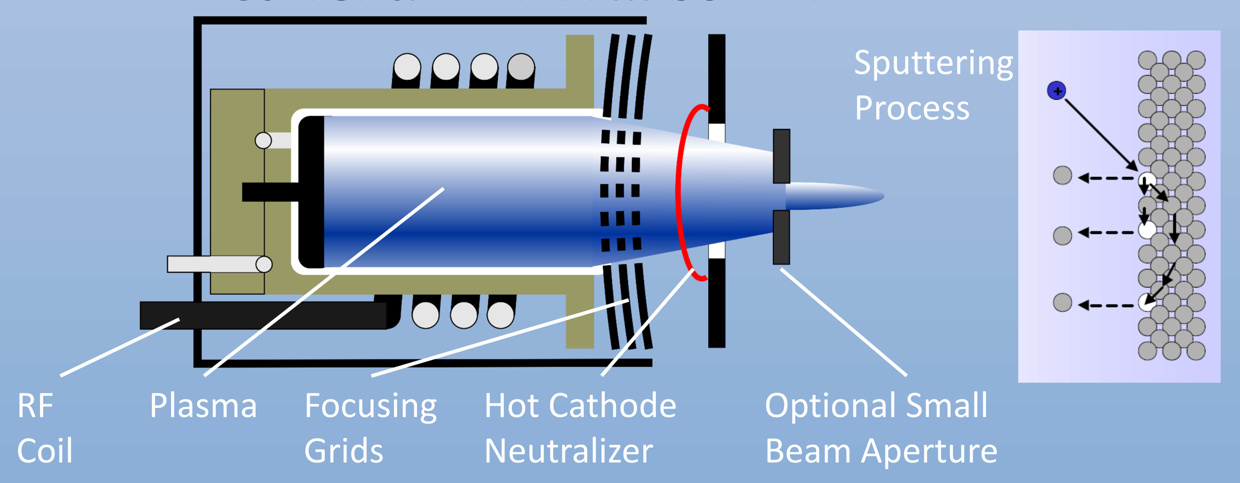
Abstract

The outstanding physical properties of diamond make it the ultimate material for the efficacy of the CO_2 lasers used to fuel the EUV light source. The efficacy of the laser is strongly influenced by the beam quality of the CO_2 laser and depends strongly on the surface quality of the optical components used in the CO_2 laser and beam delivery system. Achieving high flatness values on diamond exit windows is not trivial so new manufacturing processes are required. To achieve high flatness values on diamond, a new deterministic polishing method based on a reactive ion beam process has been developed for CVD diamond substrates in close cooperation with Element Six, a leading company in synthetic diamond technology. Optical quality diamond wafers can be grown with sizes of up to 135 mm diameter. When processed with ion beam figuring, flatness values of PV< λ/20 @ 633 nm have been achieved reproducibly, values not realized on diamond surfaces before. For transmissive optics, transmitted wavefront (TWF) values of a few tenths of fringes @ 633 nm have proven to be well within the capability of this new process technology as well. The development of a specific ion source has ensured throughput times to better than those known from more traditional polishing techniques.

IBF Basics – Ion Gun

- RF coupled Argon plasma discharge (40 W ... 150 W)
- Focusing 3-grid system with low beamlet divergency
  - Energy: 300 eV ... 1600 eV
  - Current: < 1 mA ... 60 mA



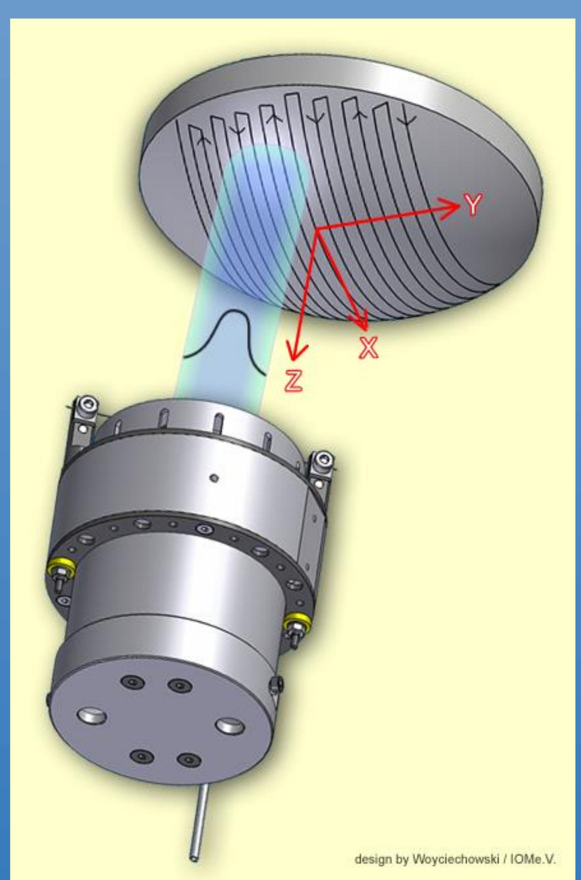
- Gaussian shape ion current distribution FWHM:
  - Different grid systems: 6 mm ... 30 mm
  - Small apertures: 0.5 mm ... 4 mm
- Volume material removal for diamond using chemical assisted ion beam process:
  - < 0.00001 mm³/min ... 0.2 mm³/min

IBF Basics – Deterministic Processing

- Long term stable ion beam removal
  - → Dwell-time controlled material removal
  - → Meander path

$$t(x,y) = \Delta h(x,y) * \hat{r}(x,y)$$

Dwell time — Height Measurement — Removal Function of Ion Beam



- Computer controlled axis system
  - High precision positioning
  - High vacuum stability
  - User friendly GUI

IBF Benefits

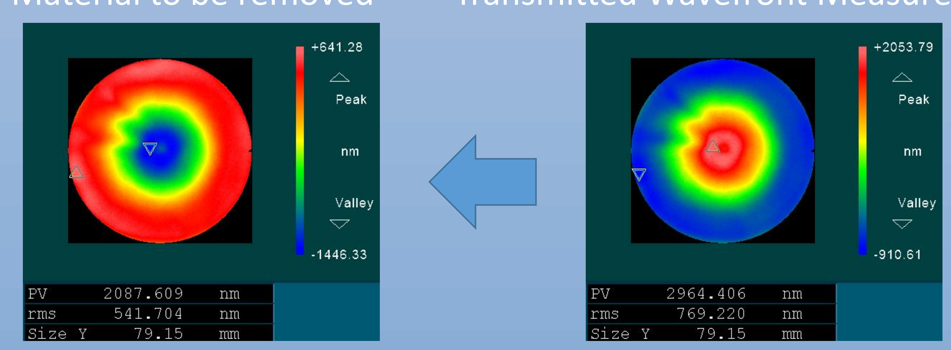
- No force closure with workpiece
  - → Independent to geometry of workpiece
  - → No negative edge effects
  - → No tool wear
- Exact calculability and controllability of process
  - →Lowest removal in pm-range
  - →Adjustable process to achieve limited result in shorter processing time (i.e. for precision optics)
  - →Generation of synthetic surface topologies
- Exact determination of removal function
  - →Highest process convergency
- Low operation costs, long maintenance intervals

IBF of Transmissive Diamond Optics D = 80 mm

- CAIBF (Chemical Assisted Ion Beam Figuring) process
- Two beam sizes for high efficient processing: 11.5 mm & 4.5 mm
- Calculation of material to be removed from transmitted wavefront measurement:

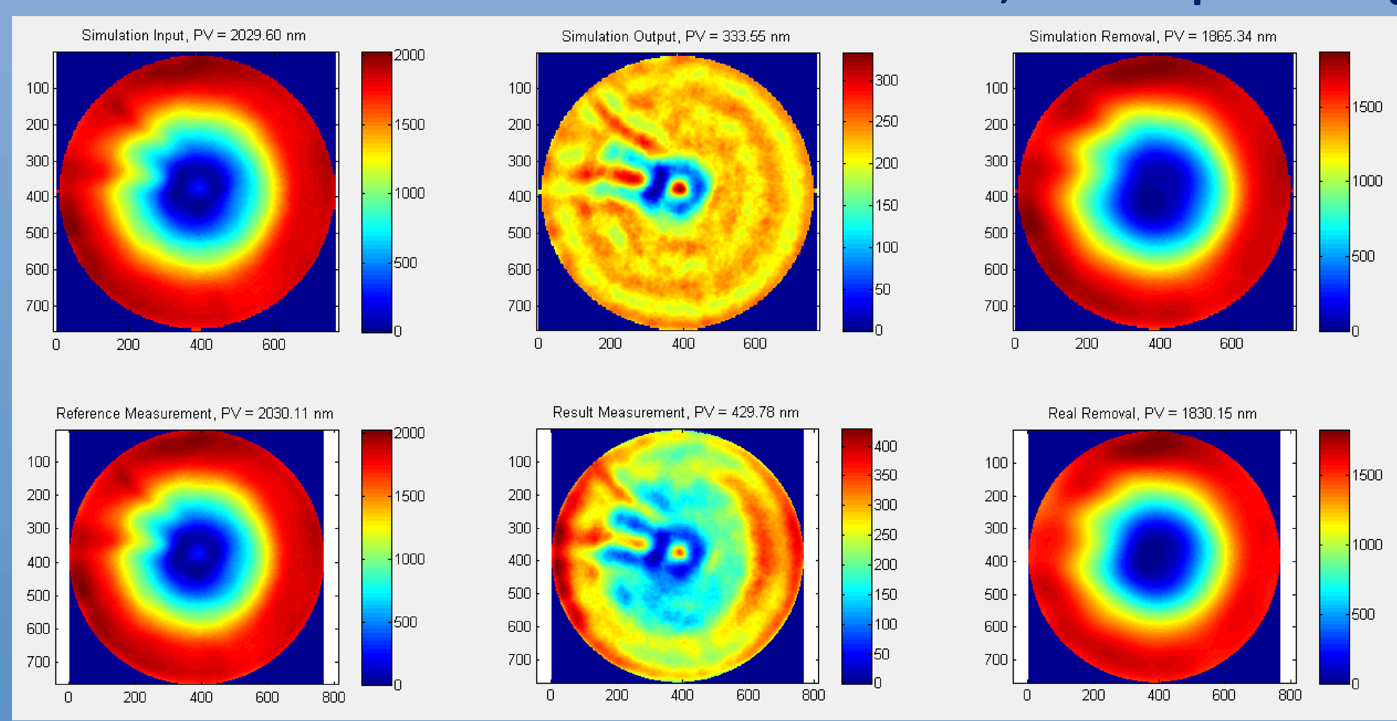
$$h_{remove}(x,y) = h_{TWF}(x,y)/(n_{air} - n_{diamond})$$

Material to be removed — Transmitted Wavefront Measurement — Refractive index difference of air (~1) and diamond (2.42)

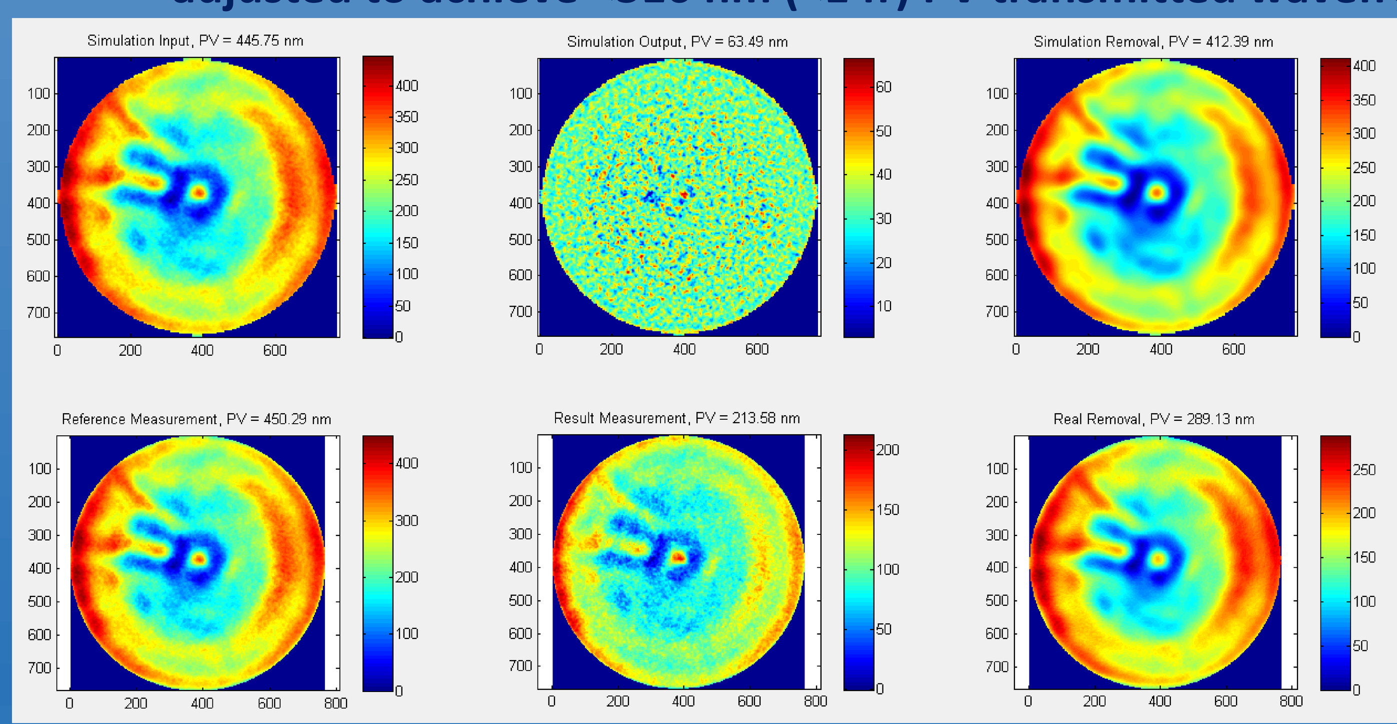


Input Values TWF
PVr = 2964.4 nm (9.4 fr)
RMS = 769.2 nm (2.4 fr)

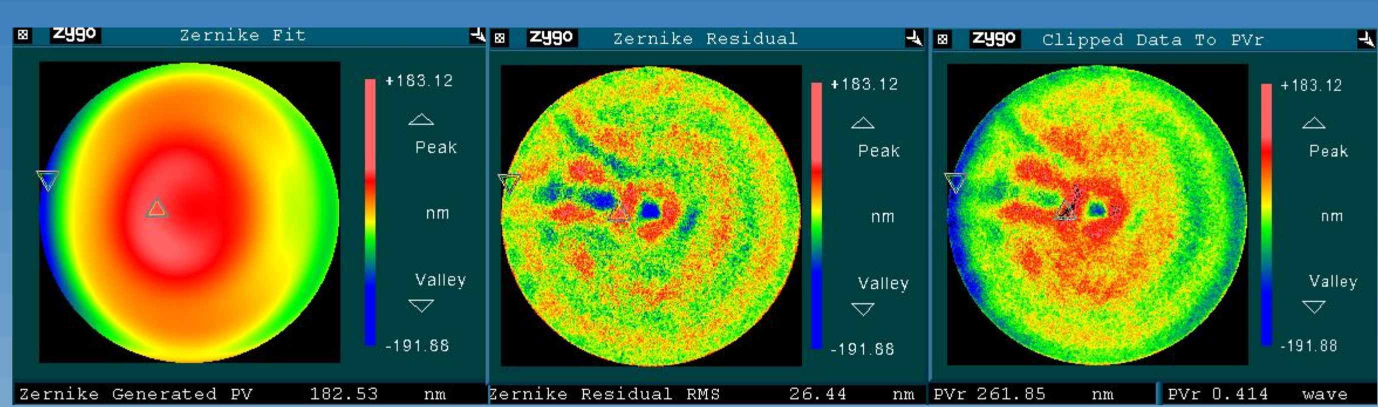
- **First IBF Process:** FWHM ion beam 11.5 mm, 18:40 h processing time



- **Second IBF Process:** FWHM ion beam 4.5 mm; 21:30 h processing time, adjusted to achieve <316 nm (<1 fr) PV transmitted wavefront result



Final Transmitted Wavefront Result:



Output Values TWF
PVr = 261.9 nm (0.8 fr)
RMS = 42.8 nm (0.14 fr)

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