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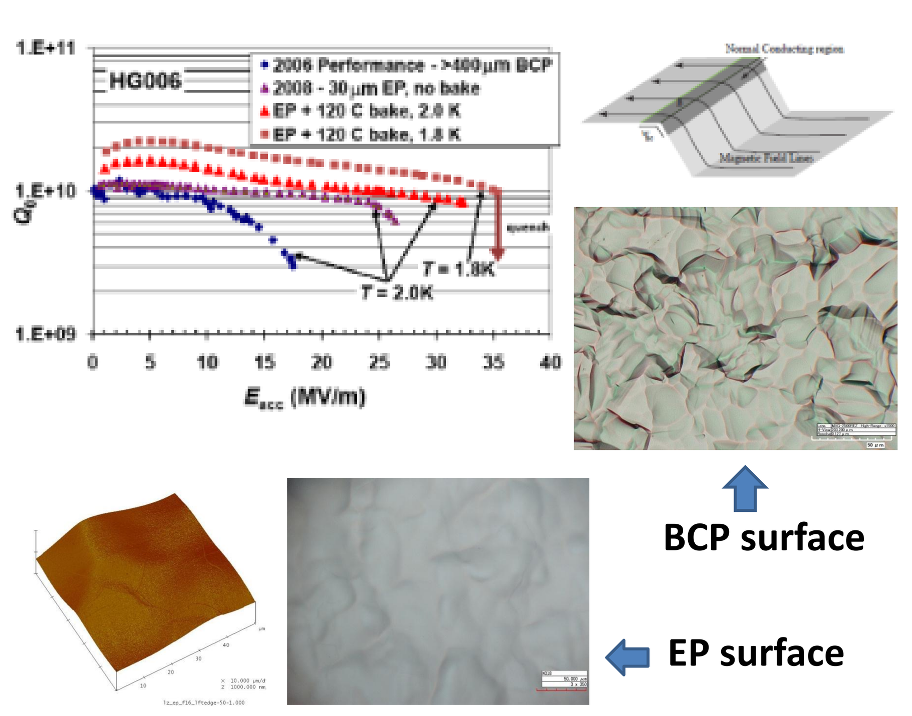
# Parameter Optimization for Laser Polishing of Niobium for SRF Applications

Liang Zhao[1,2], J. Michael Klopf [2], Charles E. Reece [2], Michael J. Kelley [1,2]
[1] Applied Science Department, The College of William and Mary, Williamsburg, VA 23187
[2] Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

## Abstract

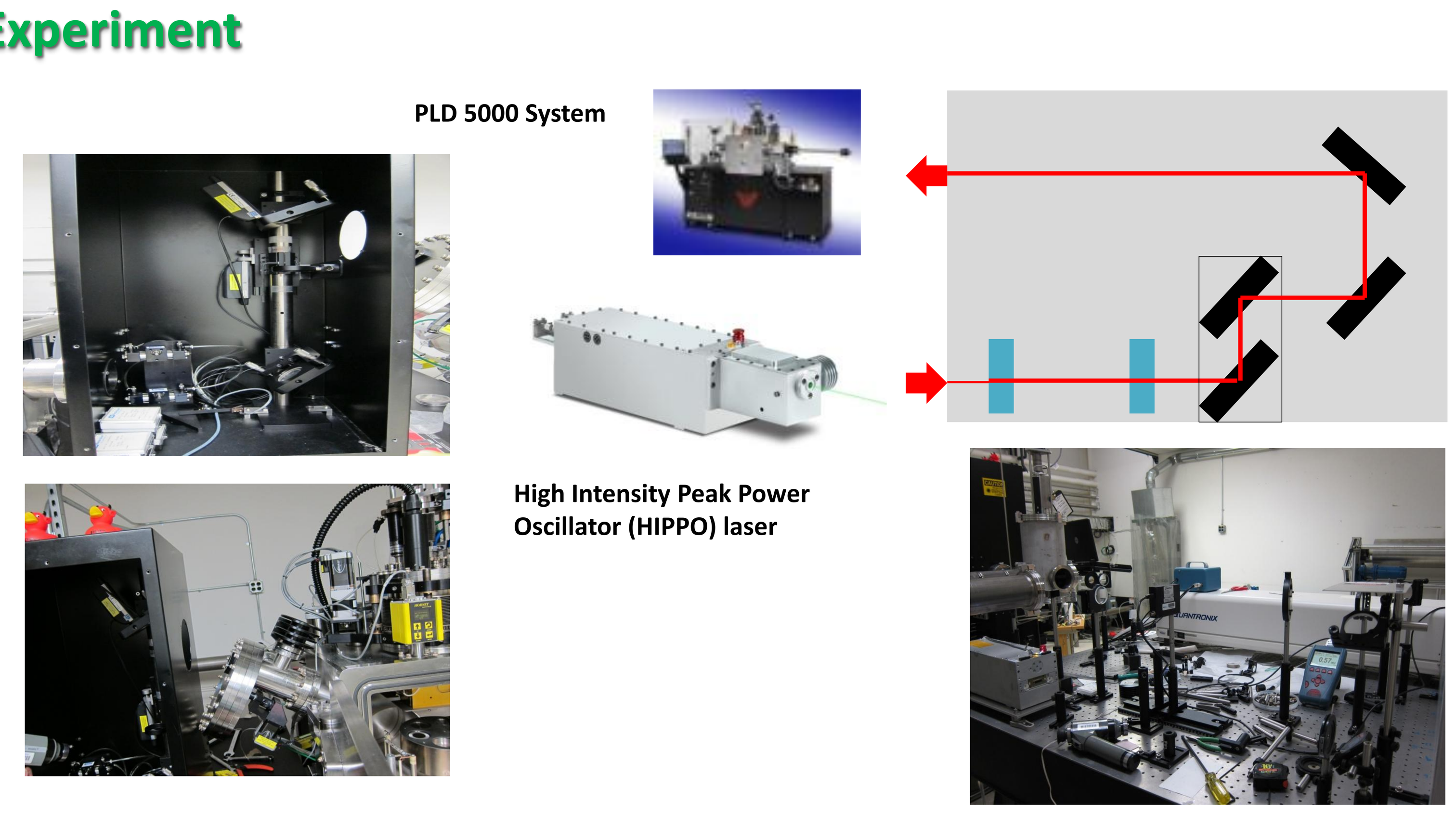
Surface smoothness is critical to the performance of SRF cavities. As laser technology has been widely applied to metal machining and surface treatment, we are encouraged to use it on niobium as an alternative to the traditional wet polishing process where aggressive chemicals are involved. In this study, we describe progress toward smoothing by optimizing laser parameters on BCP treated niobium surface. Result shows that micro smoothing of the surface without ablation is achievable.

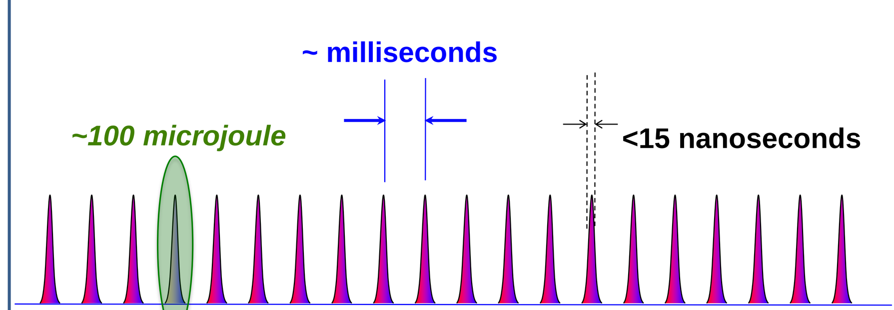
## Background




Surface topography plays a role in SRF cavity performance [1]. Commonly used BCP removes material quickly, but leaves sharp features on the surface, which may cause problems (field enhancement model [2]). EP smoothens out sharpness but removes material slowly. Both chemistry methods involve using hazardous acid and has potential of introducing hydrogen into the metal. The concept of laser polishing is to partially melt the surface to remove sharp ridges.

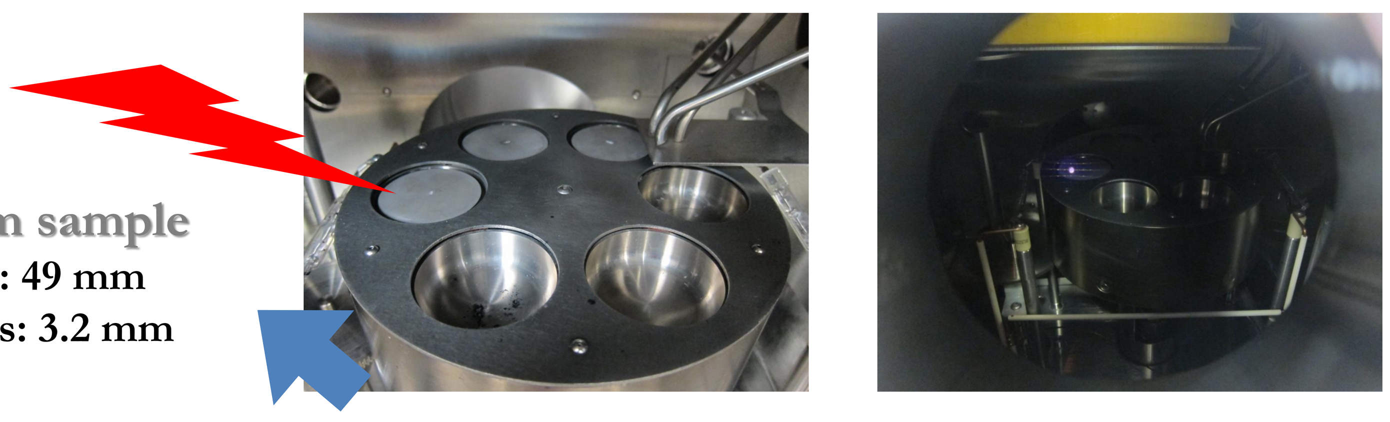
## Experiment




**Laser beam**
Wavelength: 1064 nm
Repetition rate: 19 kHz
Pulse width: ~ 8 ns
Spot size: 7.84x10$^{-5}$ cm$^2$ (FWHM)

**Niobium sample**
Diameter: 49 mm
Thickness: 3.2 mm

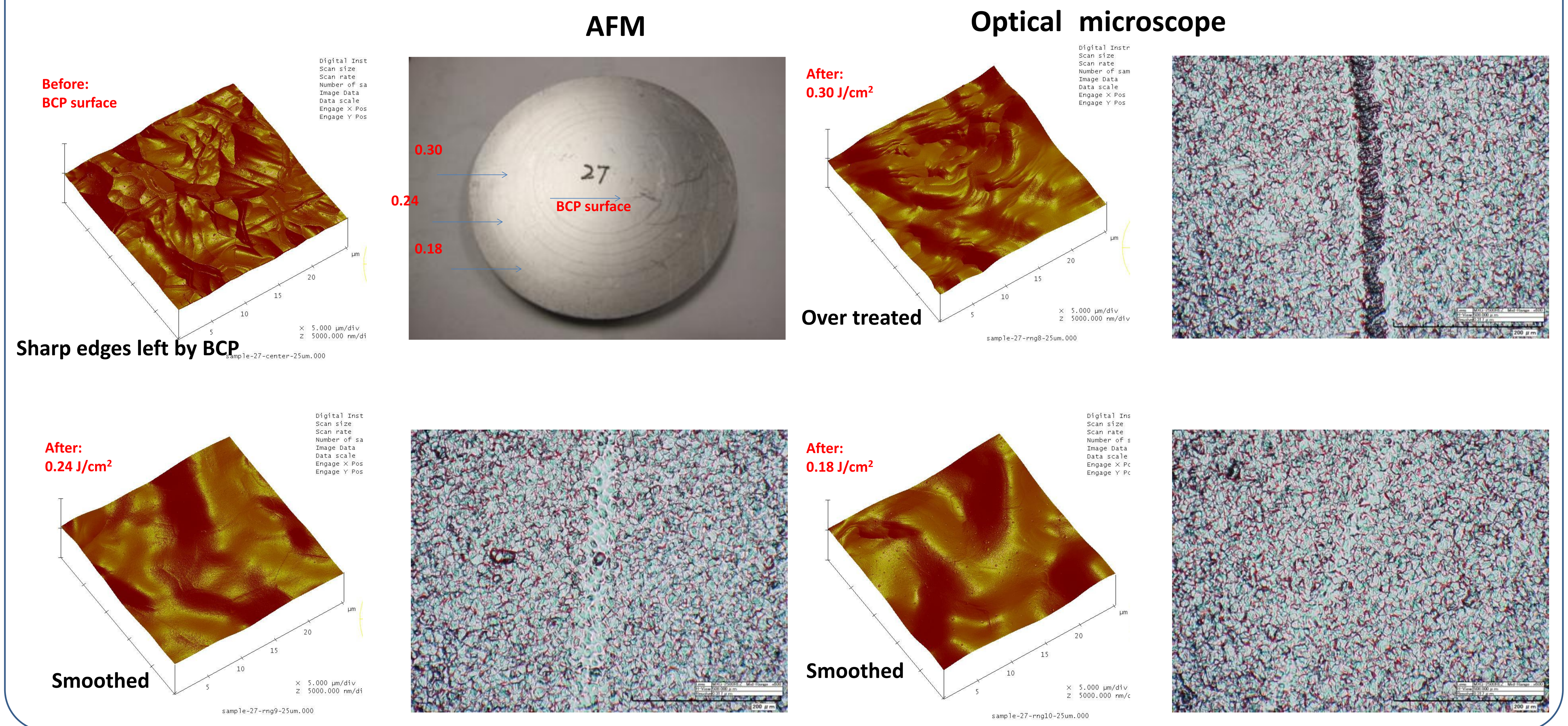


Pulse displacement 1.8 um (equivalent to a beam travel speed of 34.2 mm/s)
Treatment rate 3.6 mm$^2$/s

| Fluence (J/cm$^2$) | Laser power (W) | # of pulse overlap (per spot) | Target rotating speed (rpm) |
|---|---|---|---|
| 0.30 | 2.50 | 53 | 38 |
| 0.24 | 2.00 | 53 | 46 |
| 0.18 | 1.51 | 53 | 59 |

## Result

### Microscopy before and after laser polishing

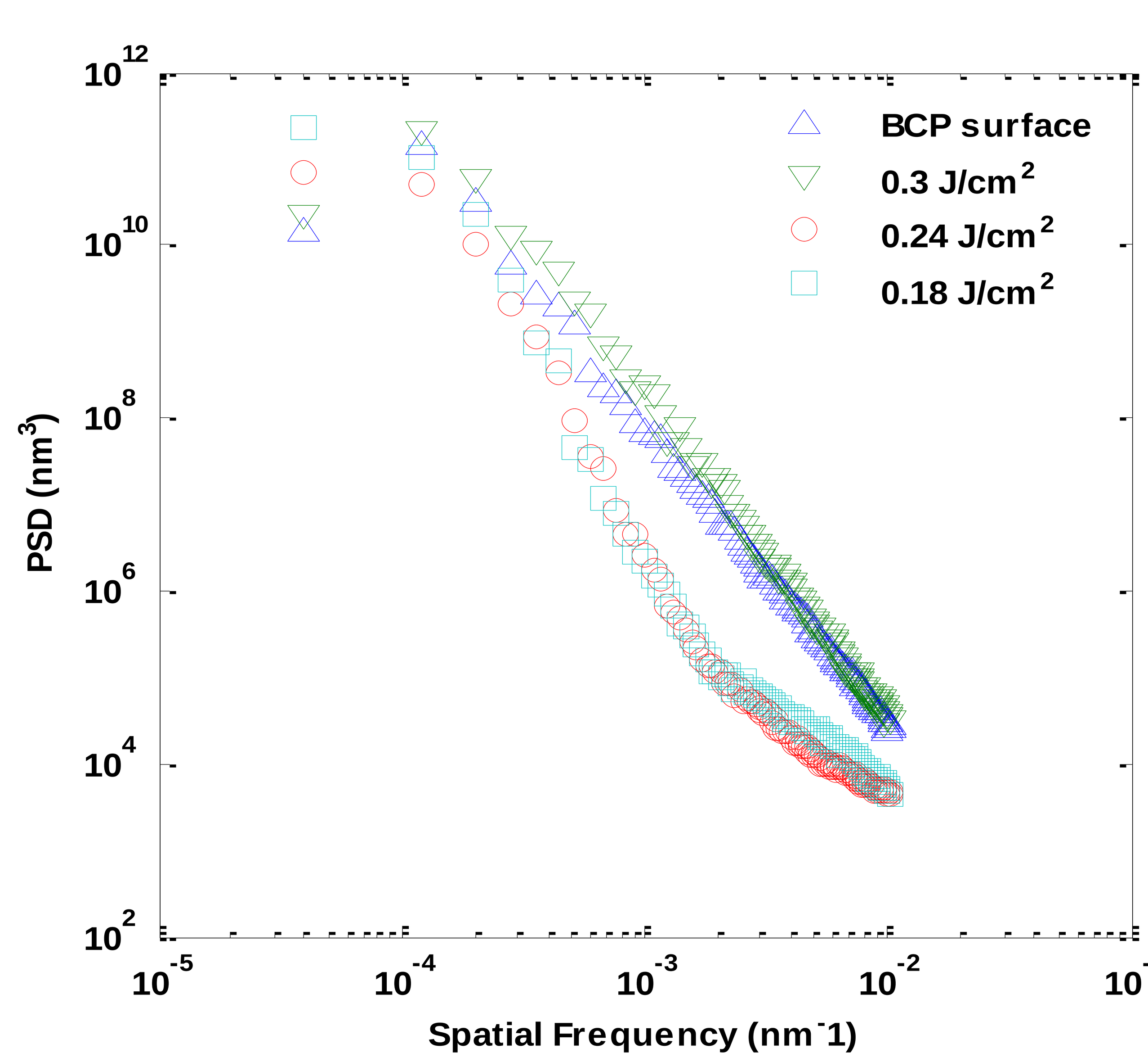



### Surface roughness before and after laser treatment at different fluences

| Fluence (J/cm$^2$) | RMS roughness (Rq) (nm) 25um area | RMS roughness (Rq) (nm) 50um area | RMS slope (Rdq) (°) 25um area |
|---|---|---|---|
| 0 (Before laser polishing) | 177.1 | 338.1 | 6.9 |
| 0.30 | 260.3 | 390.0 | 8.2 |
| 0.24 | 169.8 | 248.2 | 4.3 |
| 0.18 | 234.5 | 242.2 | 5.2 |

### Power spectral density (PSD)

- ❑ PSD provides detailed description about surface roughness and topography. Contributions from features at different scales are plotted as a function of spatial frequency. Surfaces with sharp edges (like BCP surface) usually show a straight line on PSD, while smooth surfaces (like EP surface) shows a curved PSD with two distinguishable stages.
- ❑ Smoothing effect from laser polishing is comparable to electropolishing (EP) in terms of PSD analysis [3]. PSD value greatly reduced at high spatial frequency range from several microns to hundreds of nanometers.
- ❑ Partial melting is preferred over full melting, which can leave “sharp” ridges and ripples.




### Potential applications on niobium cavity

Engineering feasibility - The CavitY CaLibrated Optical Profilometry System (CYCLOPS) – an internal interferometric profilometry can map and profile the interior of a elliptical cavity [4].

## Conclusion

- ❑ By selection of proper parameters, laser smoothing is achievable.
- ❑ For a pulse displacement of 1.82 um, a fluence of ~ 0.18 – 0.24 J /cm$^2$ is enough to melt the surface without damaging it. Microscopy shows that sharp edges are removed, and the step at grain boundary are smoothed as well. However, over-treating can result in sharp ripples.
- ❑ Laser polishing is a promising candidate for surface polishing in the pursuing of environment friendly and fast treatment methods.

**Reference**

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