Dielectric Laser Accelerators

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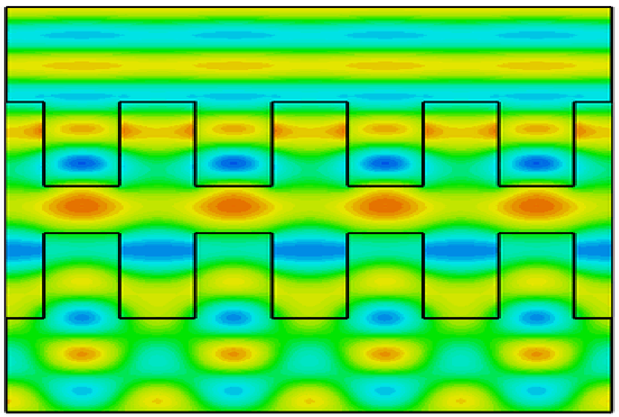
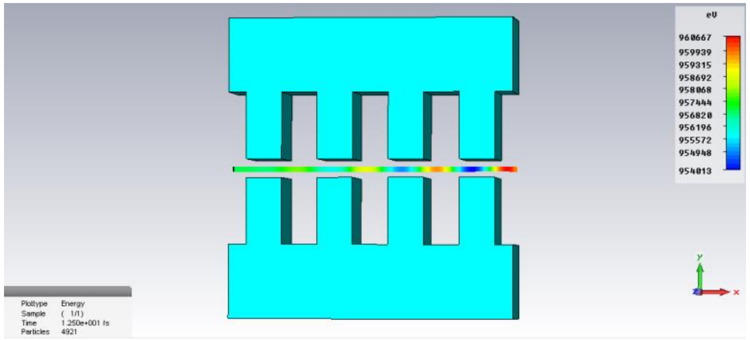
Close collaboration with STFC, PSI and Radiabeam

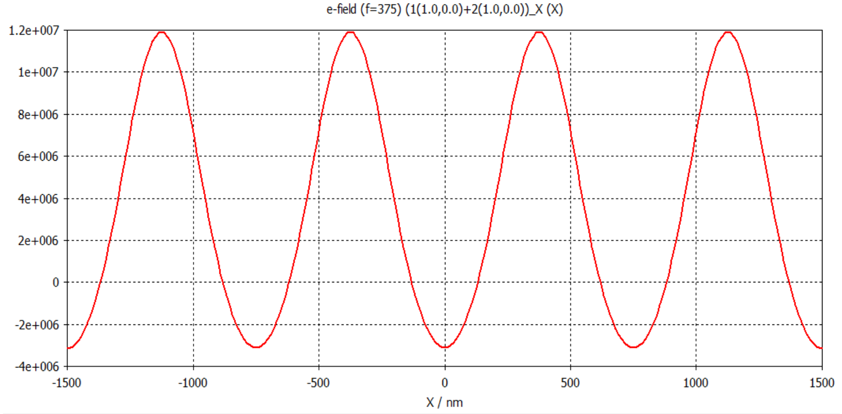
Introduction



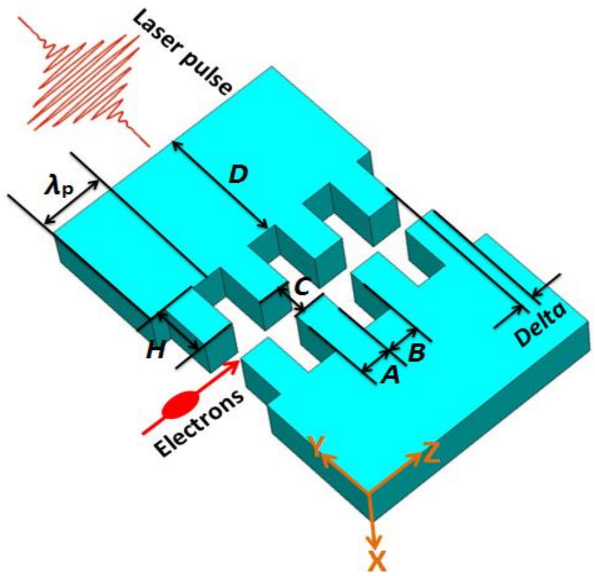
Challenges

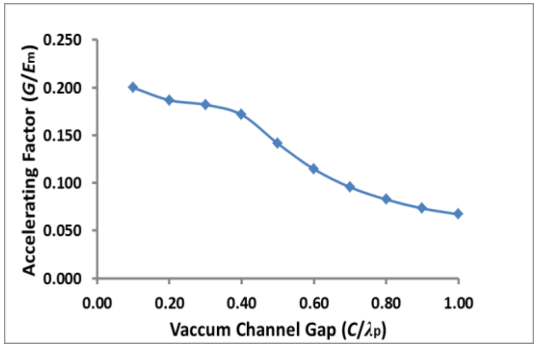
- Structure geometry
- Field distribution
- Optimization of accelerating gradient
- Understanding and optimization of output beam quality

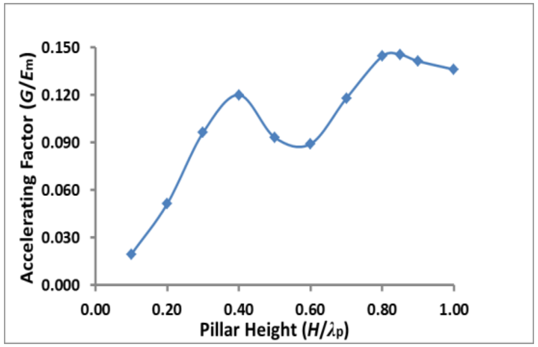


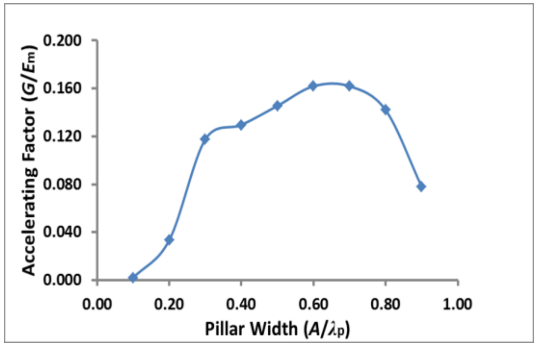


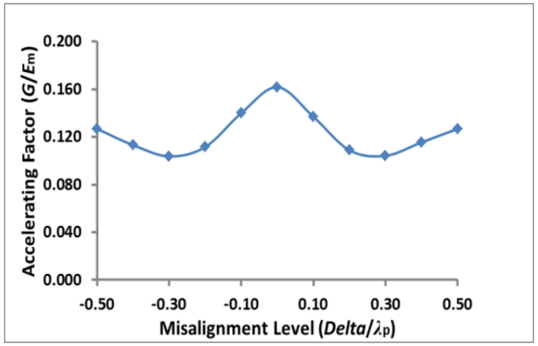
Structure optimizations for DLA





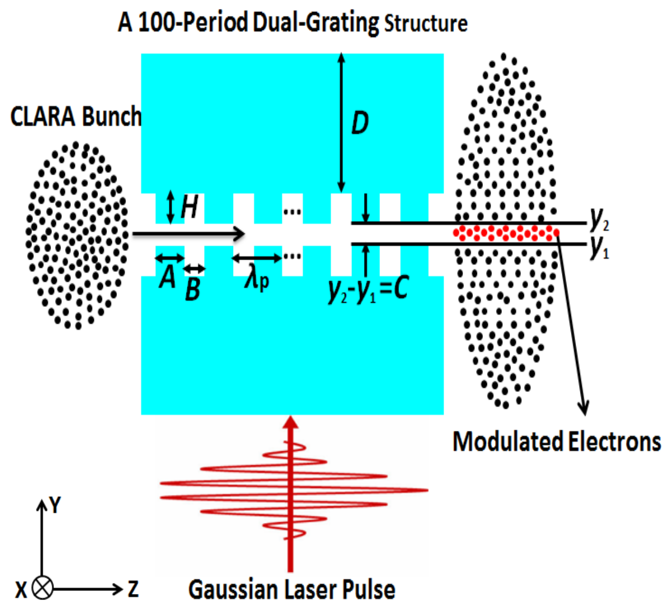






- 2D/3D simulation studies using CST Studio and VSim
- 1.5 GV/m for Quartz found as maximum gradient

Beam Quality Study



- Material: quartz(n=1.50);
- Grating period λp= 2.0 μm, 100 periods;
- Vacuum channel width C= 0.5λp;
- Pillar height H=0.85λp;
- Pillar width A=0.60λp

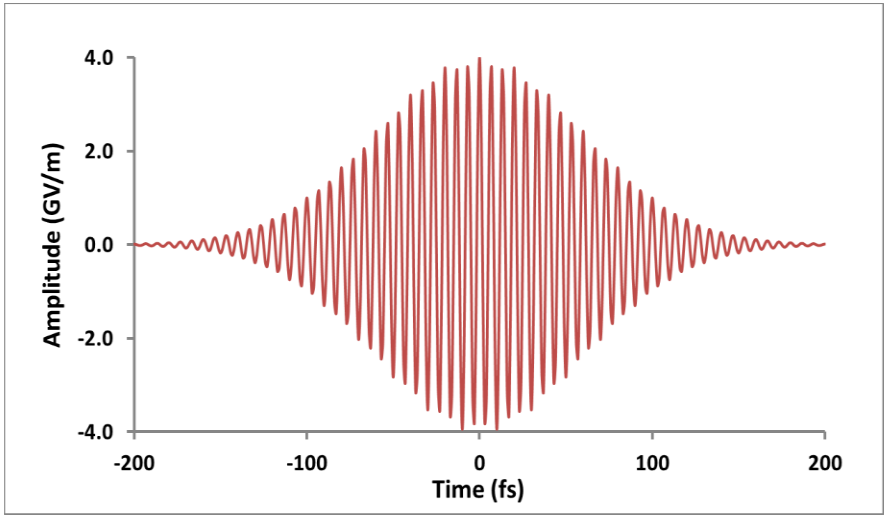
Structure Parameters

- Bunch Energy: 50 MeV
- Bunch charge: 0.05 pC
- Bunch RMS length (Z axis): 9 μm
- Bunch RMS radius (Y axis): 10 μm
- Norm. RMS emittance (Y axis): 0.3 μm
- Energy spread: 0.05%

Bunch Parameters

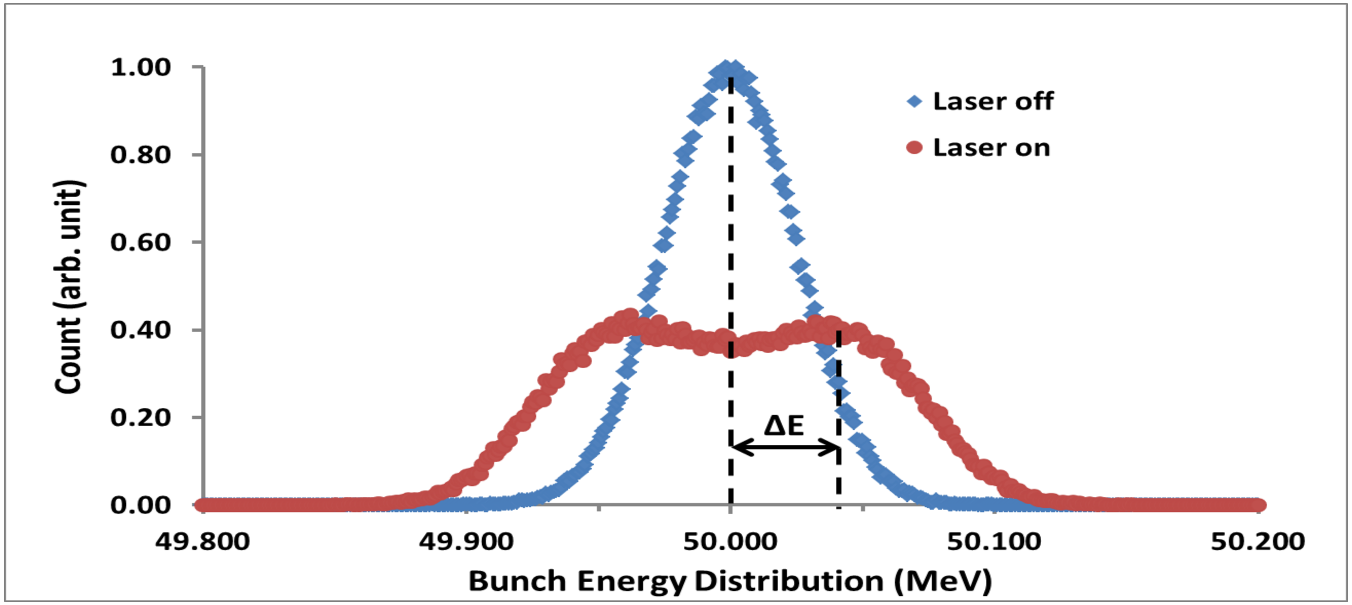
Gaussian Laser Pulse Parameters

- THz wavelength: λ_p=2.0 μm
- Peak laser field: E_p=4.0 GV/m
- Pulse duration (FWHM): τ=100 fs
- Waist radius: w_z= 50.0 μm



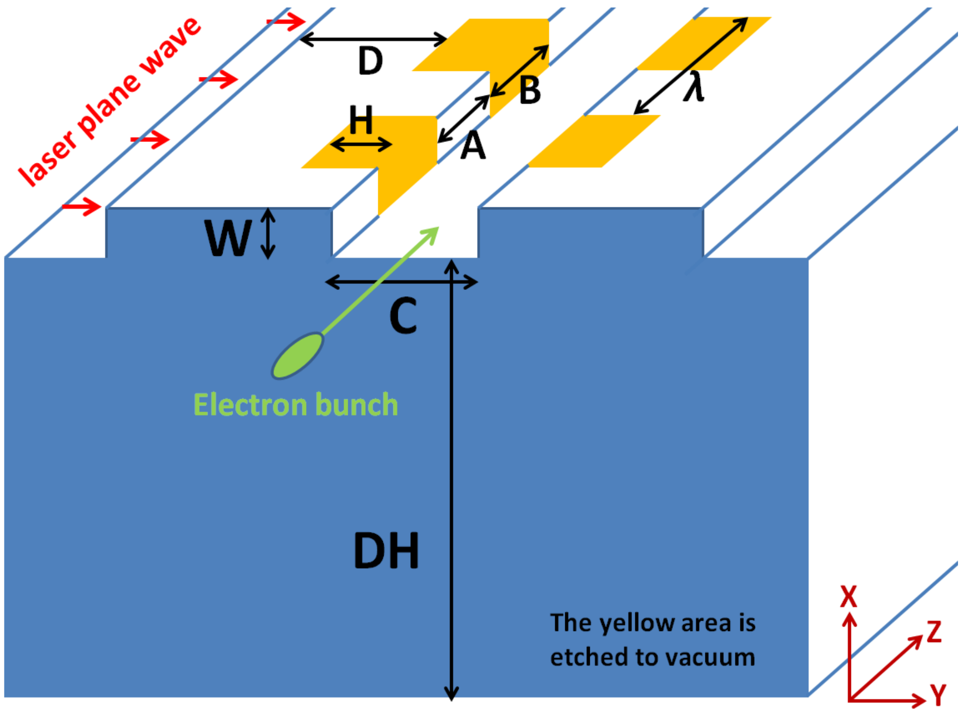
1) **Interaction length is w_{int}=22.702 μm;**
2) **Integration of temporal field with a peak gradient of G_p = 1.0 GV/m results in a maximum energy gain 40.24 keV.**

Energy modulation



1) From the particle tracking simulations, the RMS emittance is 8.2 nm for those modulated electrons when the bunch travels out of the structure, corresponding to an increase of 2.50% compared to that of the laser-off case with 8.0 nm;
2) A double-peak profile for bunch energy distribution and demonstrates that the maximum energy gain is ΔE = 44 ± 3 keV, corresponding to a maximum accelerating gradient of G = 1.10 ± 0.07 GV/m

Geometry for fabrication

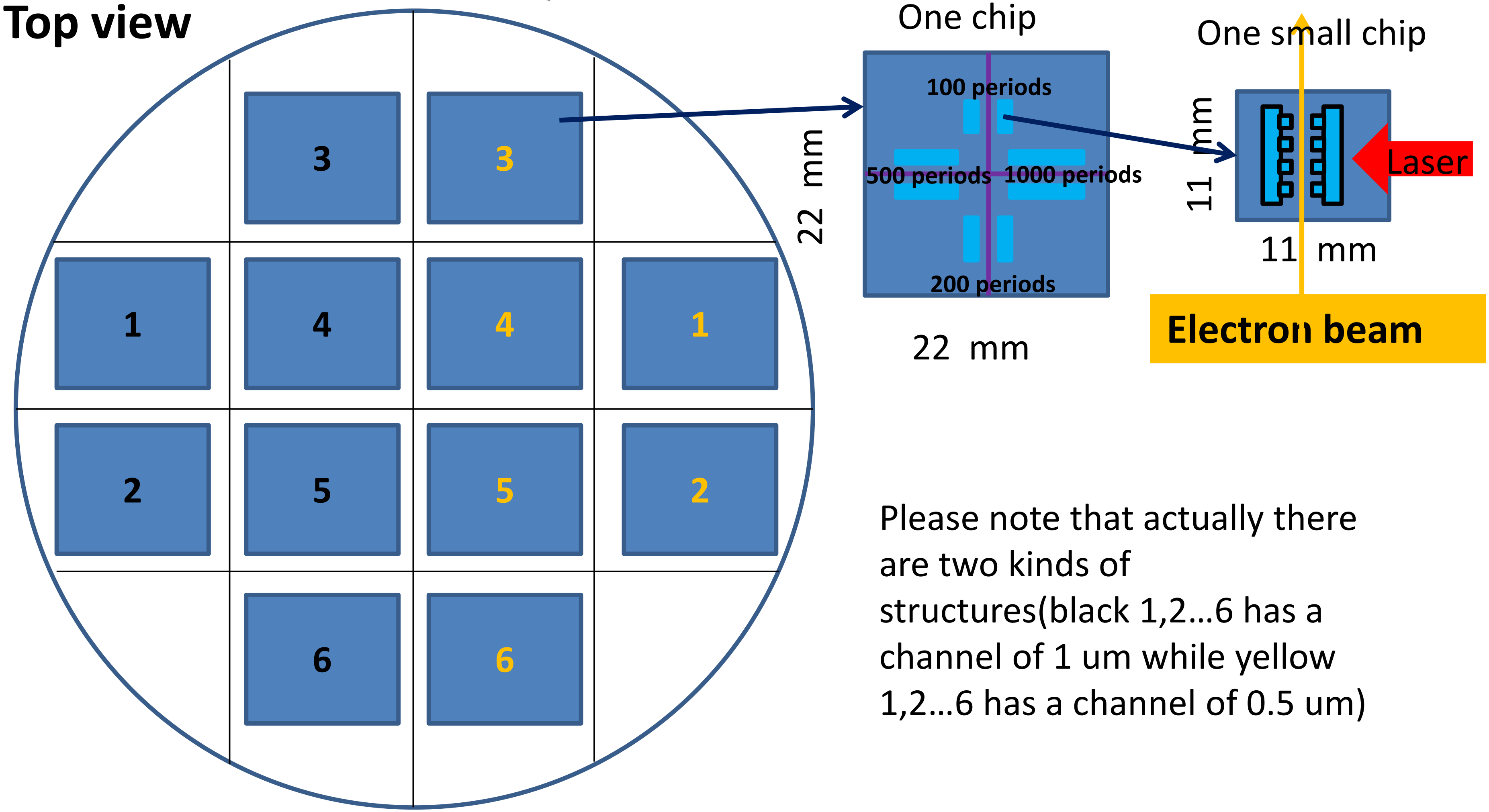


Double grating structure geometries	
material	Quartz(refractive index=1.50)
Number of periods	100, 200, 500, 1000
Grating period λ	2 µm
Vacuum channel gap C	1.0 µm=$0.50\lambda_p$, and 0.5 µm=$0.25\lambda_p$
Pillar height H	1.70 µm=$0.85\lambda_p$
Pillar width A	1.20 µm=$0.60\lambda_p$
Trench width B	0.8 µm=$0.40\lambda_p$
The depth W	several µm (to be discovered)
D	several µm
DH	500 µm

The most important parameter is W, which is desirable to be larger than 10 µm.
This month we have etched a channel gap with a depth of W=8 µm.

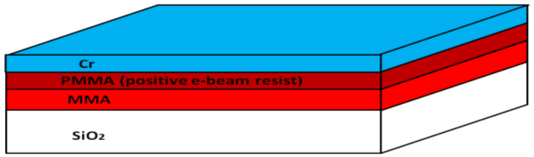
Structure pattern in the Quartz Wafer

Top view

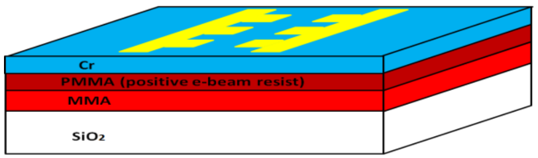


Please note that actually there are two kinds of structures(black 1,2…6 has a channel of 1 um while yellow 1,2…6 has a channel of 0.5 um)

Fabrication procedure

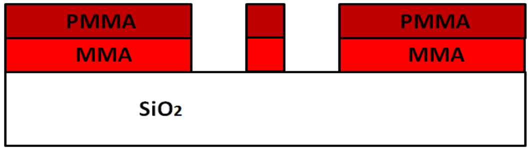


Deposit MMA and PMMA layers as e-beam resist; Deposit a Cr layer to prevent surface charging



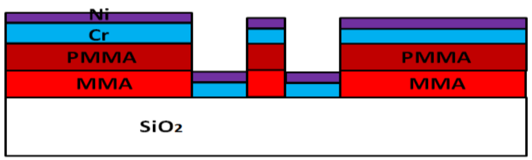
Exposed to e-beam for lithography, where exposed a weaker chemical compound forms (yellow part) for PMMA and MMA, while other parts not exposed by e-beam feature stronger chemical compound.

Side view



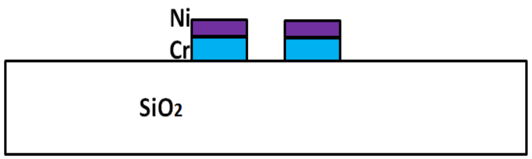
Chemicals are then used to remove the Cr layer; developer etches the weaker PMMA and MMA away.

Side view



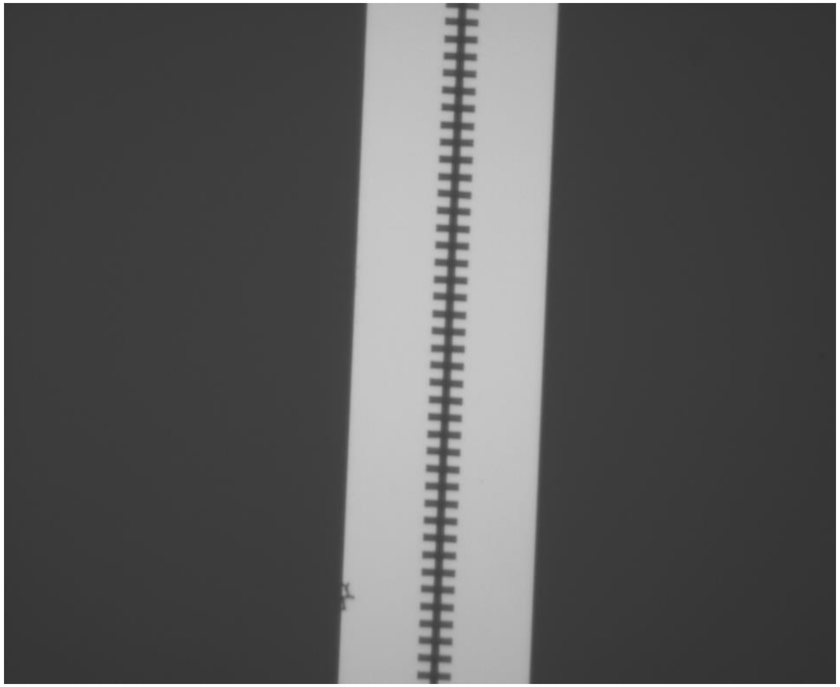
A layer of Cr with a thickness of 200 nm and a layer of Ni with a thickness of 50 nm are deposited.

Side view

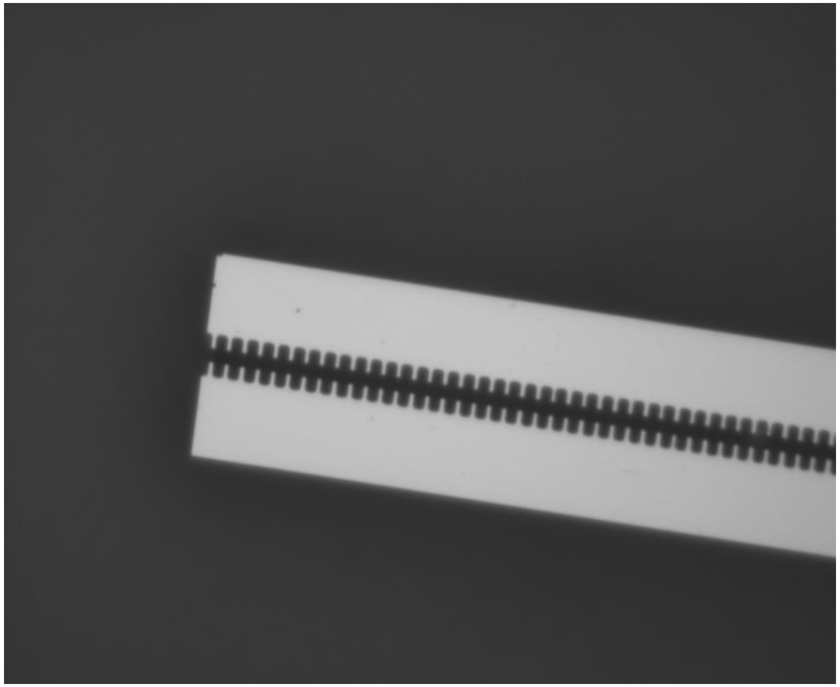


The wafer is put into Acetone, only Cr and Ni layer covering the structure pattern are left on the surface of structure. Finally it is put into RIE 100 for plasma etching.

Microscopic images



Before etching



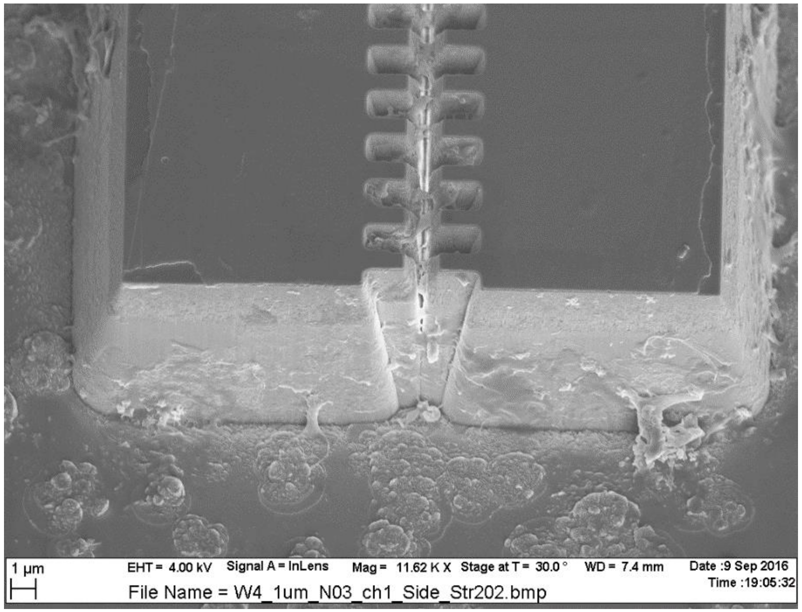
After etching

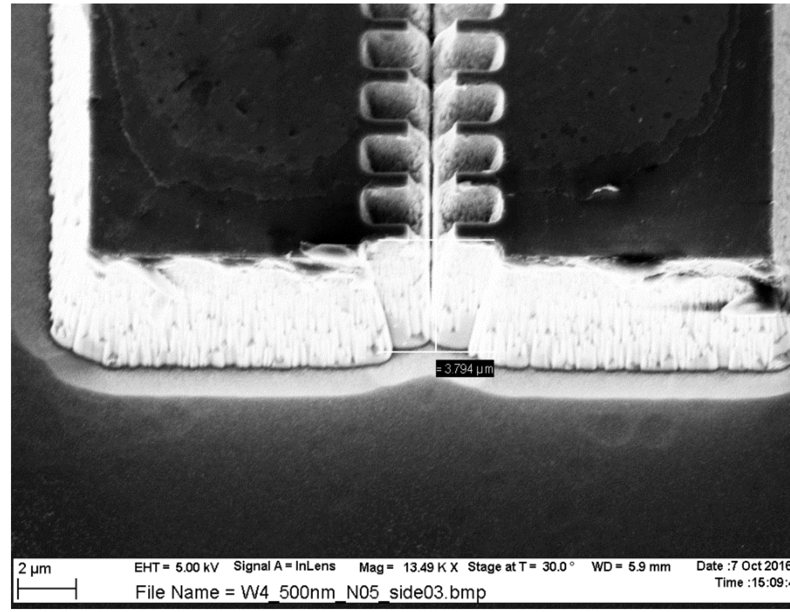
The structure pattern (pillar width) is changed a little bit by plasma.

The Cockcroft Institute
of Accelerator Science and Technology

QUASAR

SEM Images





Etching at 0 degree Celsius

Etching at -10 degrees Celsius

- Using current etching recipe we can get a channel depth of 7.6 µm.
- We have shown that the roughness and wall skew can be improved by lowering the etching temperature.
- This structure shall now be tested with pump laser;
- further optimization possible to get a more uniform channel and good roughness.