Carrier Dynamics of Semiconductors

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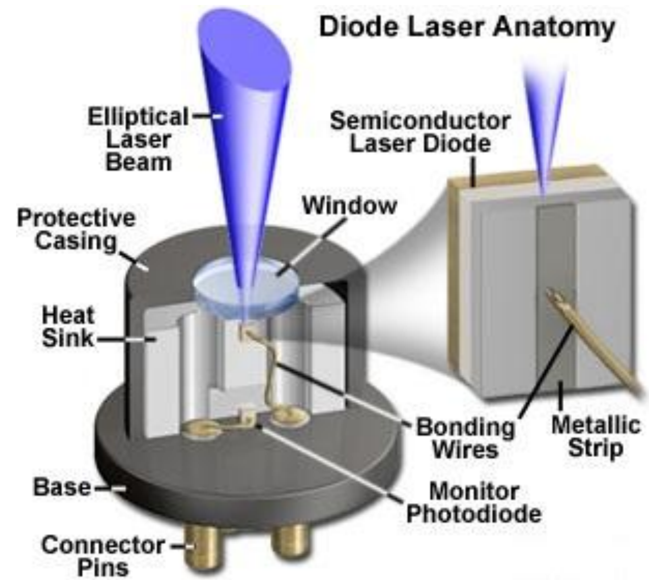
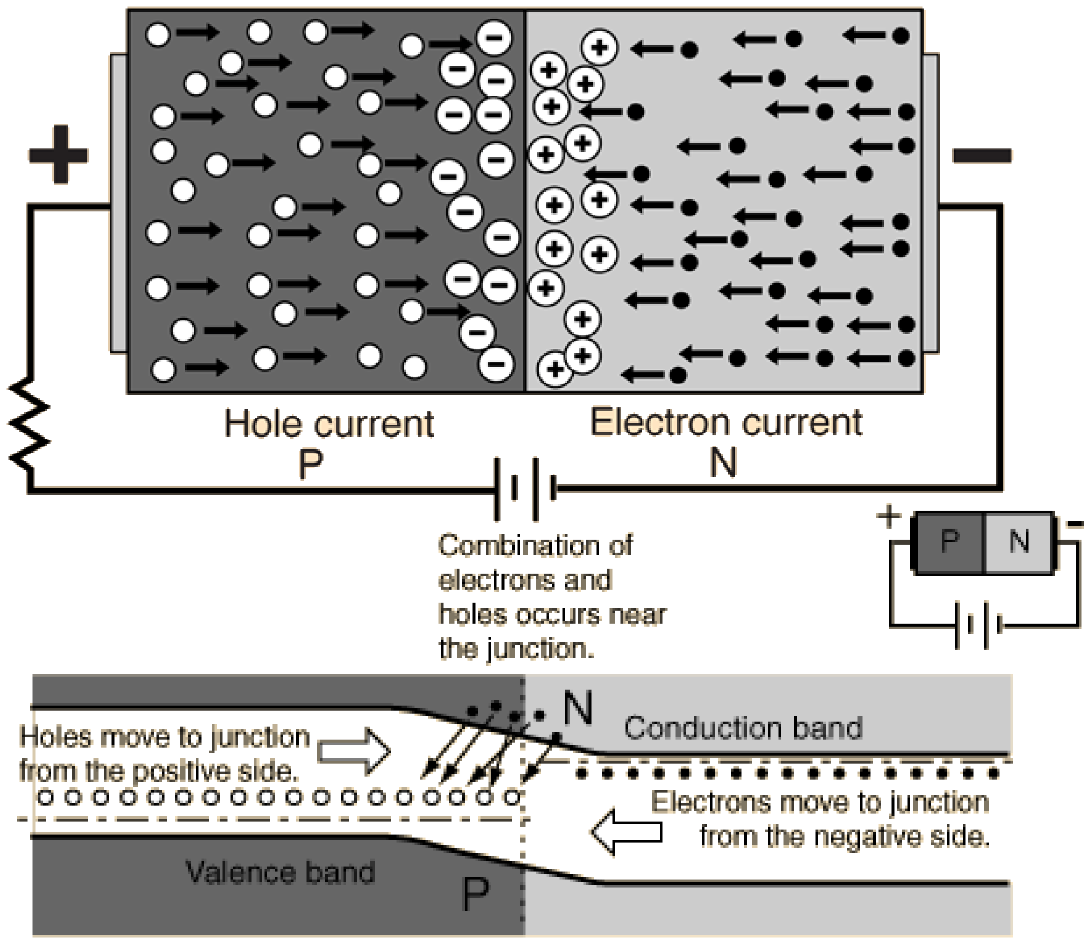
Why Semiconductor Diodes are Awesome

- Cost effective
- Durability
  - Fragile glass environment
  - Mirror alignment
- Small size vs. laser output
- Can be implemented in various environments



Semiconductors

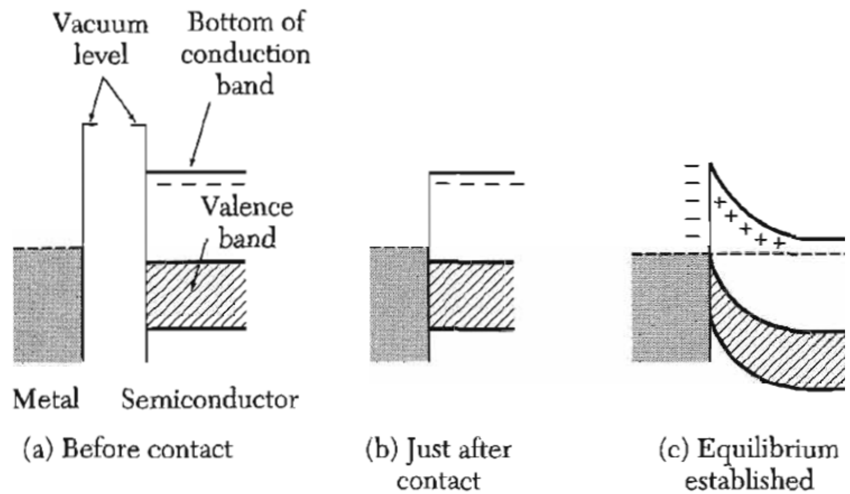


p-n junction

Schottky Diodes

- Lower voltage drop
- Higher switching speeds
- High reverse current leakage
- Thermal Sensitive metal
  - Less power dissipated

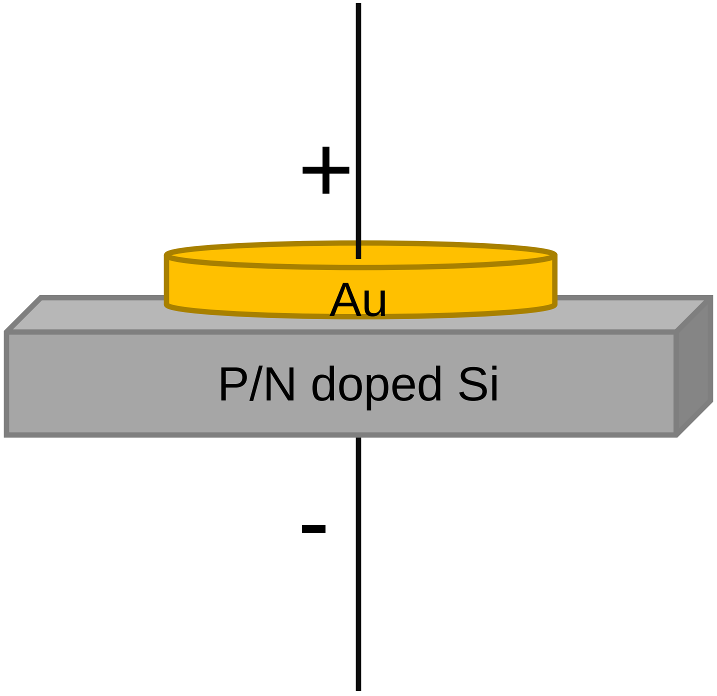
– Less durable



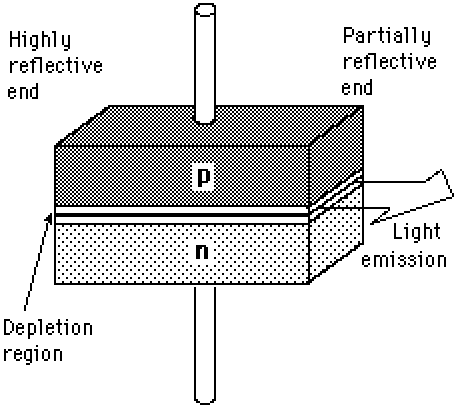
Rectifying barrier between a metal and an *n*-type semiconductor. The Fermi level is shown as a broken line.

Dopants

- P-type: lower forward voltage (0.5 – 0.7V)
- Increased doping
  - decreased depletion
- Very high doping levels
  - Ohmic contact

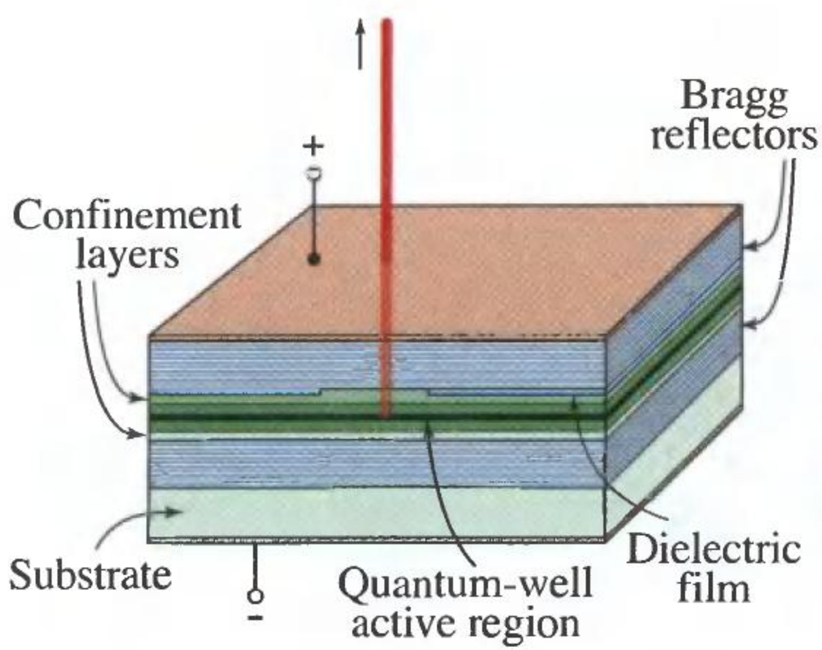


Laser Diode



- Mirrored ends flat and parallel
- Length of junction related to wavelength emitted
- Recombination process produces light

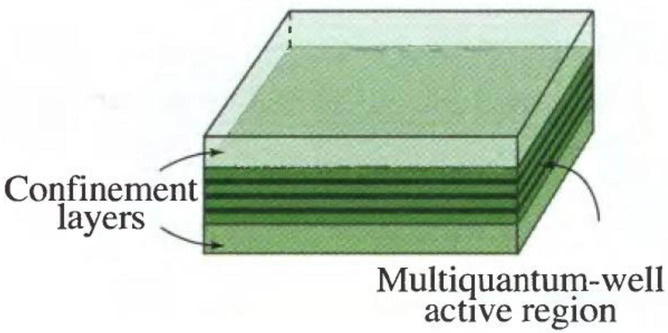
Quantum Well Laser



Schematic representation of quantum confined lasers in quantum-well

- Carrier confinement smaller than deBroglie wavelength
- Structures decreases, depletion width decreases
  - Lower threshold current
  - Narrower laser line width

Multiquantum-Well Laser

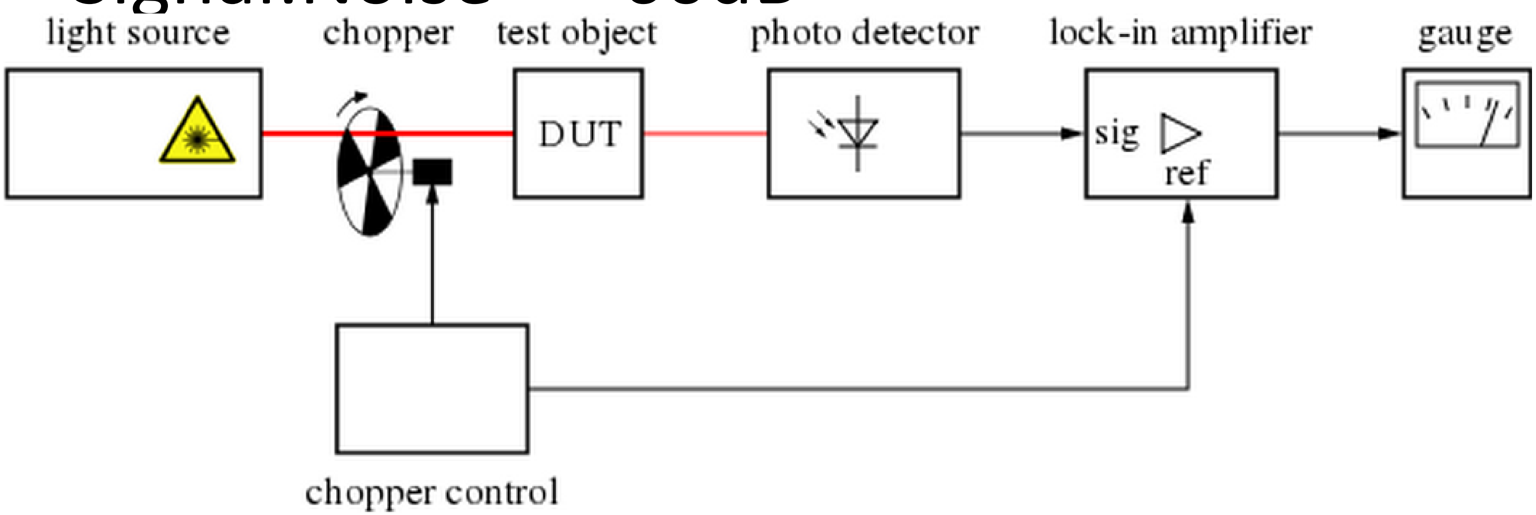


Schematic of the active region of a multiquantum-well laser. The confinement layers restrict charge carriers to the quantum-well region.

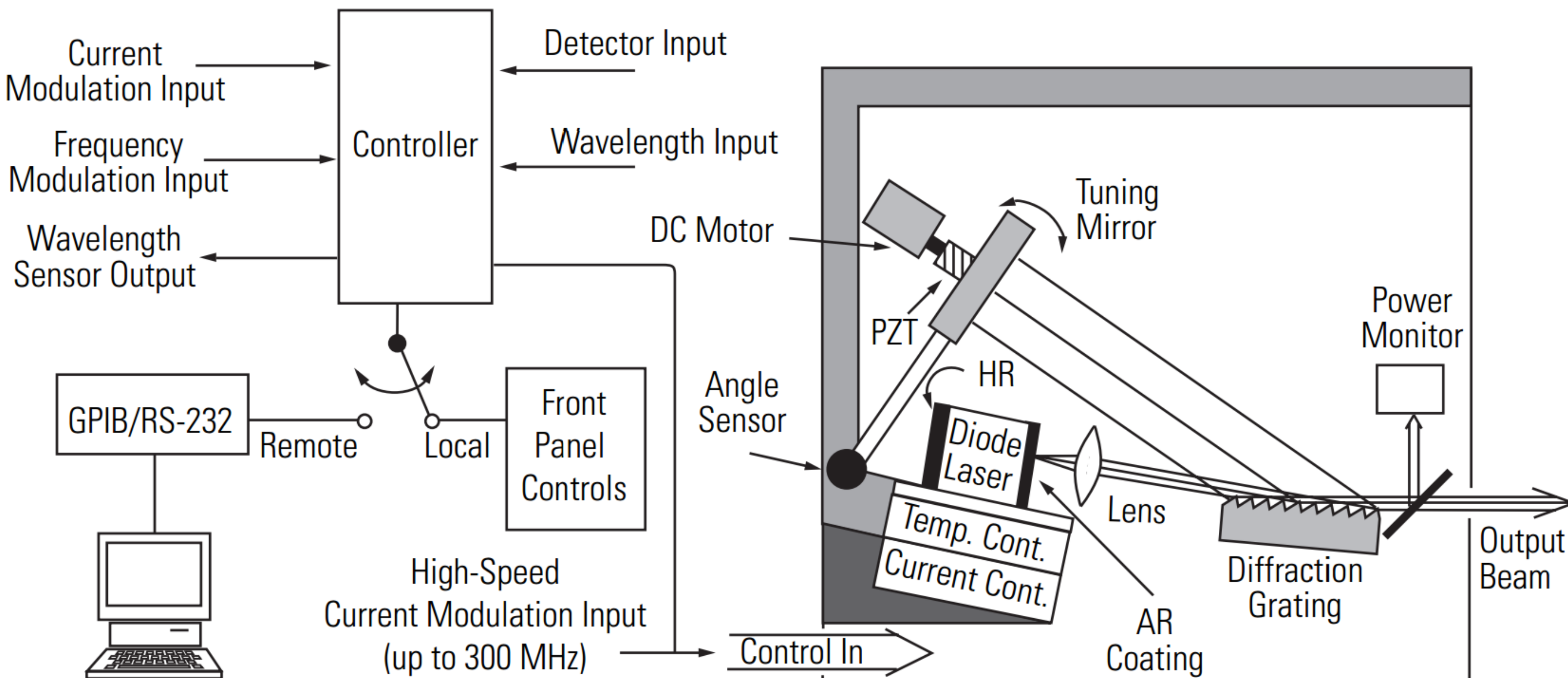
- Increase in…
  - External quantum efficiency
  - Power-conversion efficiency
  - Response: modulation frequencies
- Less temperature dependence
- MQW: Gain increases by N, number of wells

Lock-In Amplifier

- Utilizes optical chopper as reference signal
- Extracts signal from noisy environment
- Converts AC signal to DC signal
- Outputs to oscilloscope
- Signal:Noise = -60dB

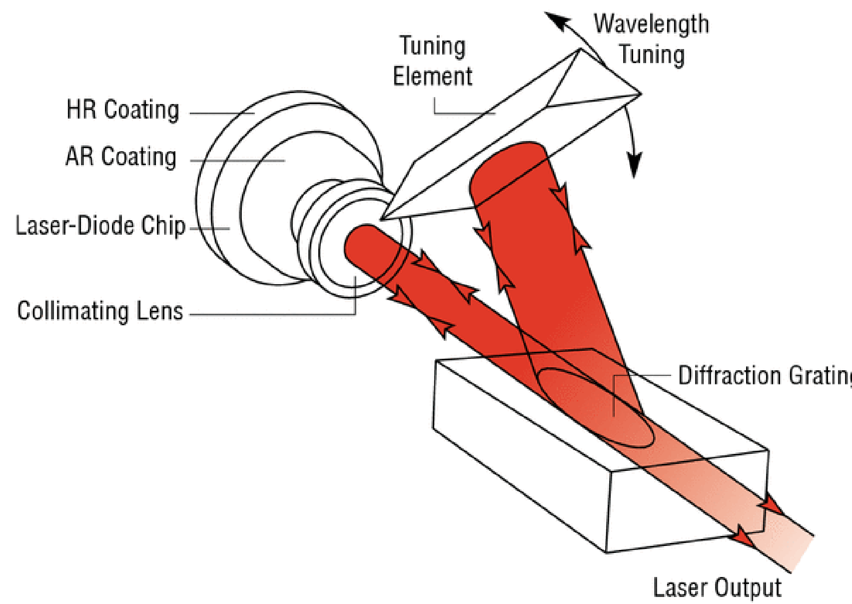


Tunable Diode Laser

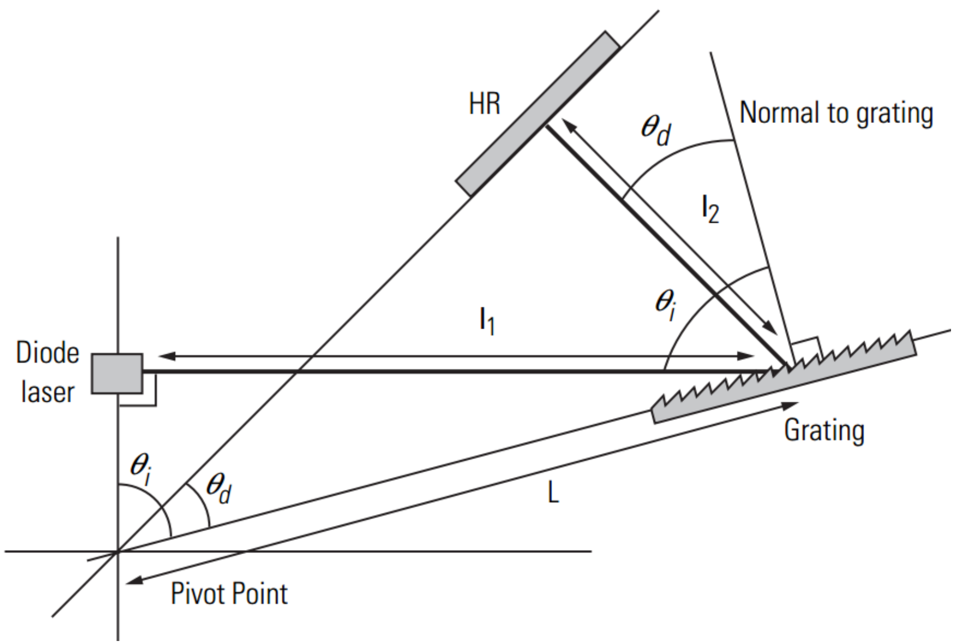


Tunable Diode Laser

- Corse Adjustment:
  - Light diffracts off of Bragg grating in Littman-Metcalf cavity
  - Motor controls mirror that reflects light from Bragg grating
  - Light reflected and the perpendicular component reflected off the grating is the first order diffraction outputted

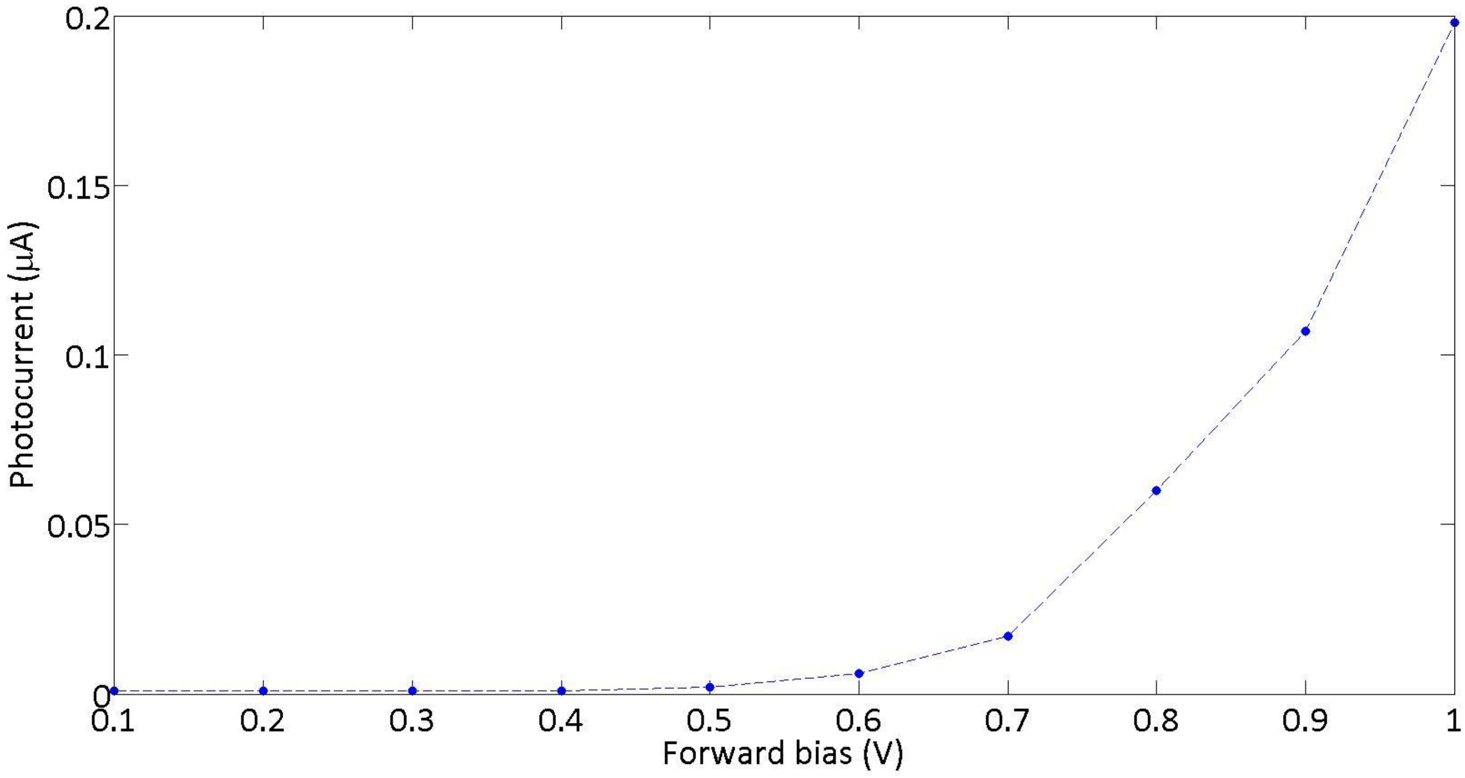


Tunable Diode Laser

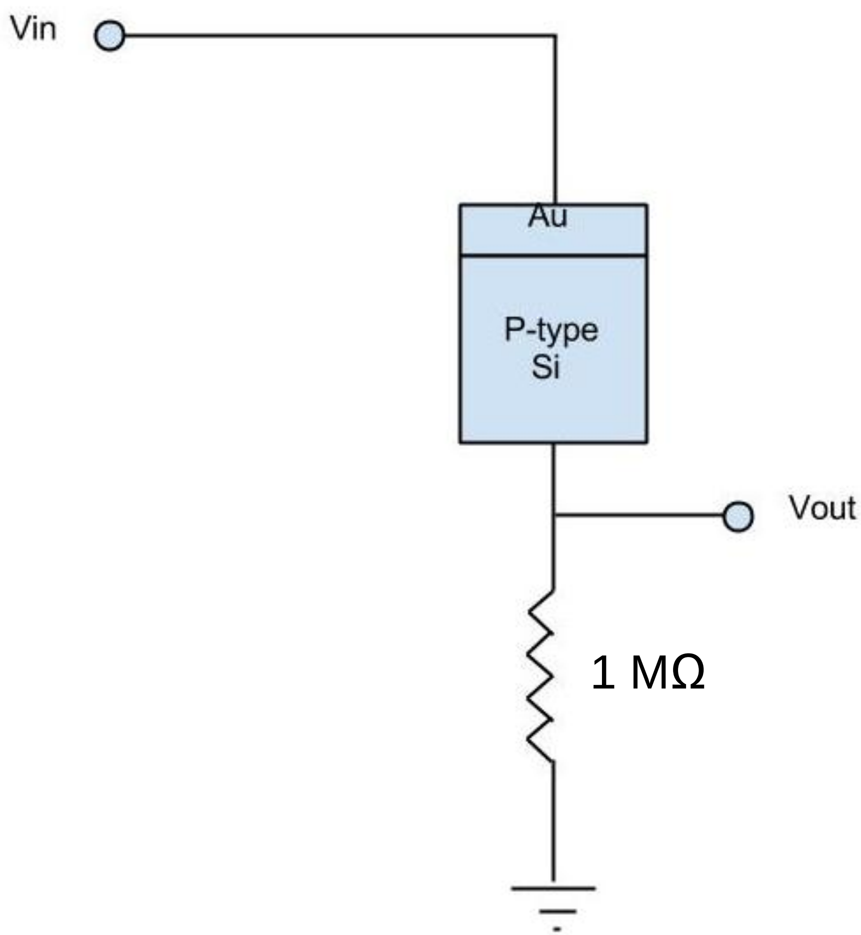


- High wavelength selectivity due to spacing of Bragg grating and the near grazing angle of incidence
- Grating diffracts the beam twice also giving high resolution of wavelength.
- No mode hopping due to a constant number of waves in the cavity:
  - $\lambda = \Lambda(\sin\theta_i + \sin\theta_d)$

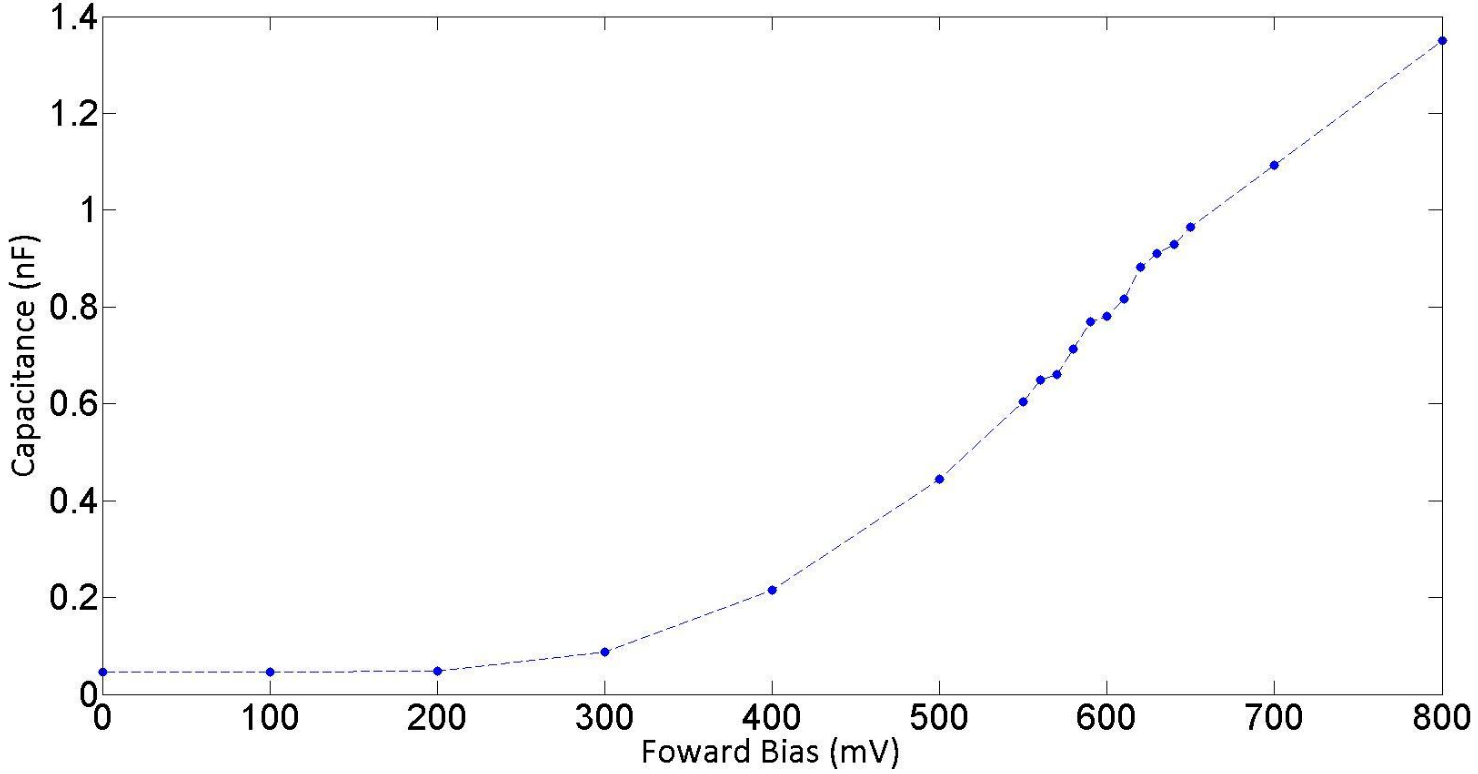
Voltage Threshold Schottky



Capacitance

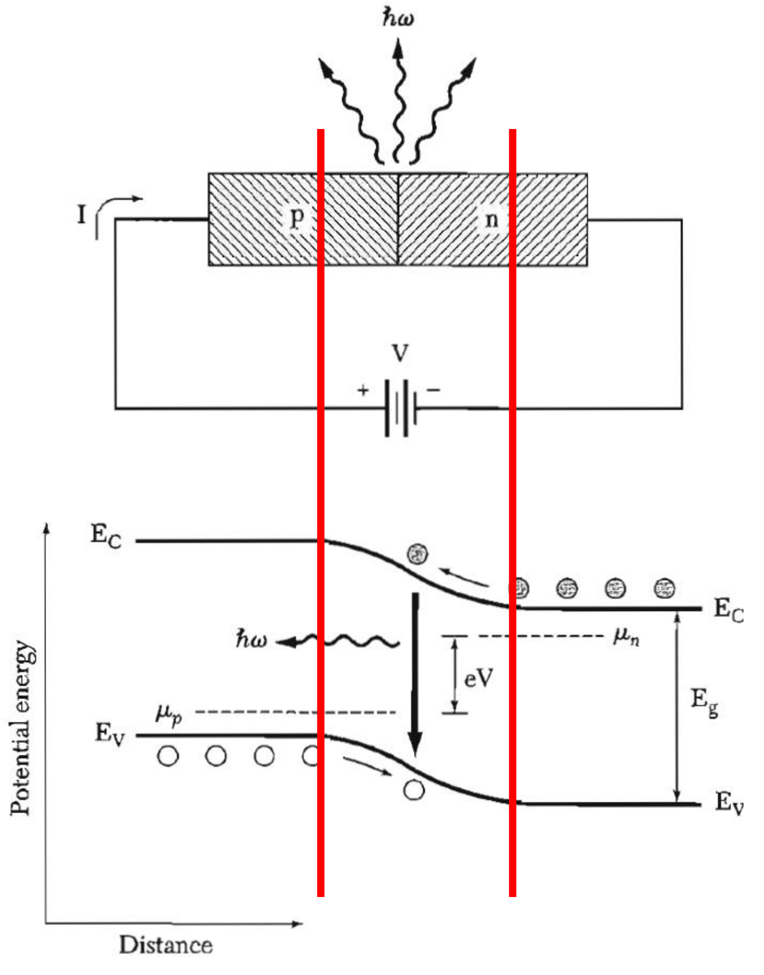


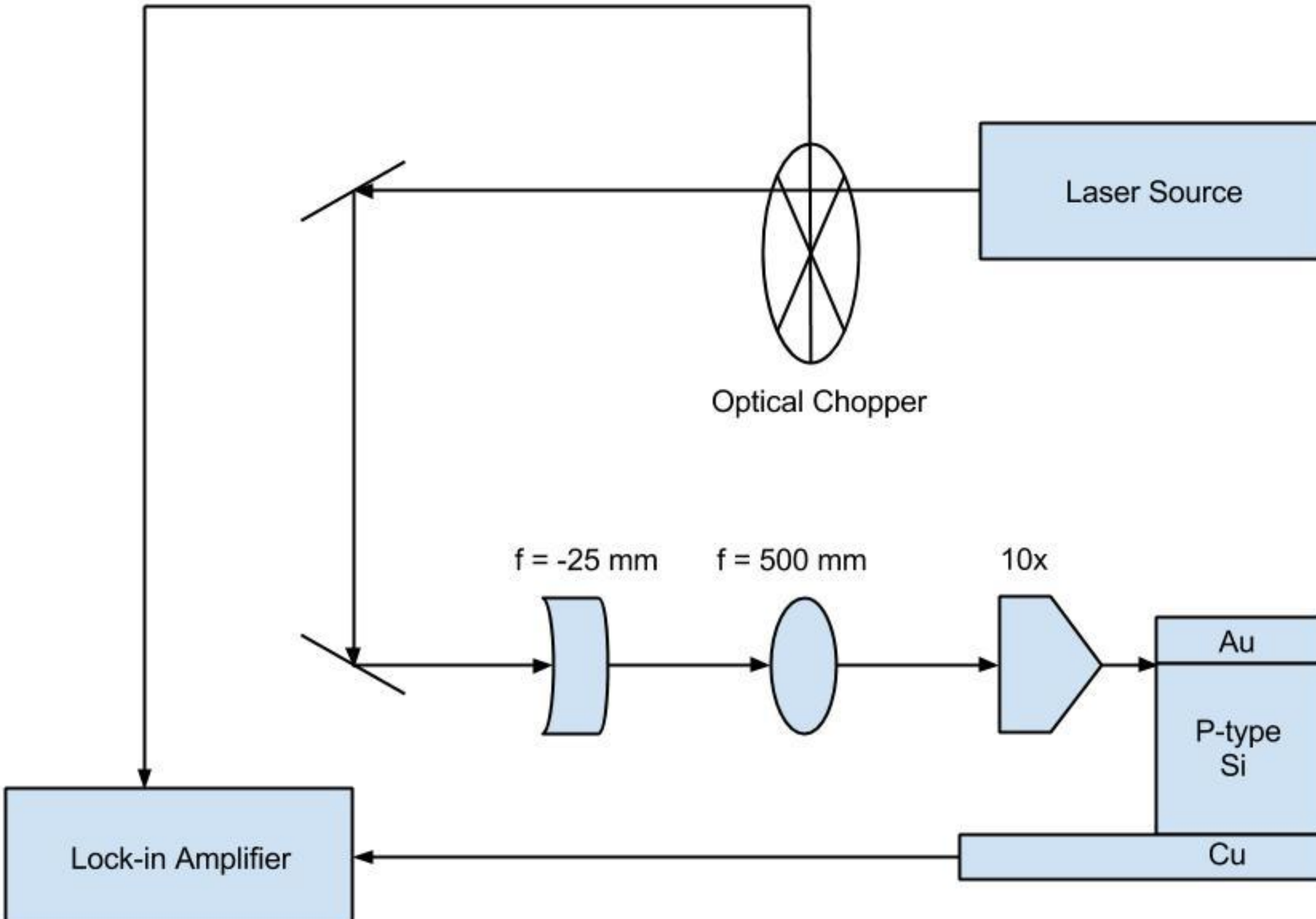
Capacitance Schottky



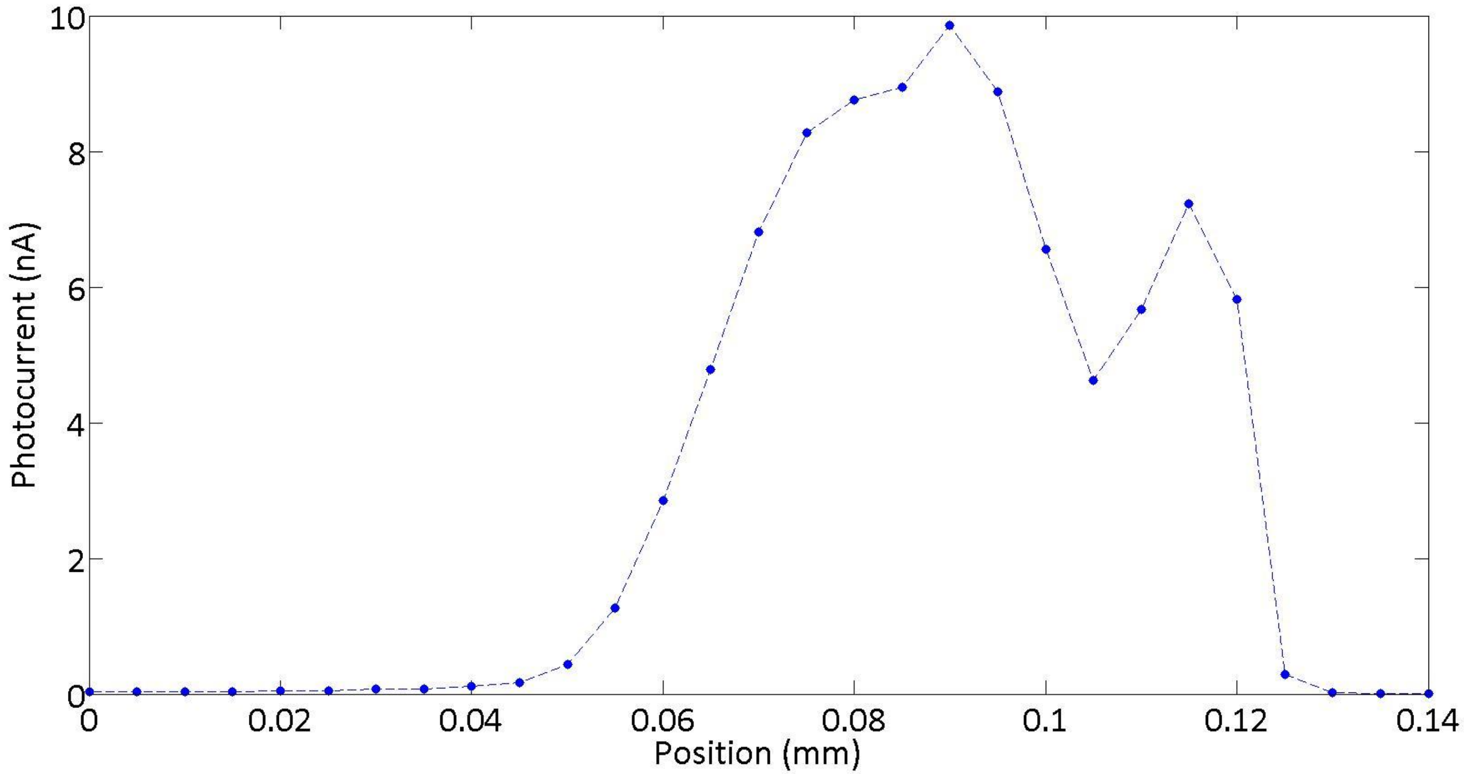
Capacitance

- C = σ/x

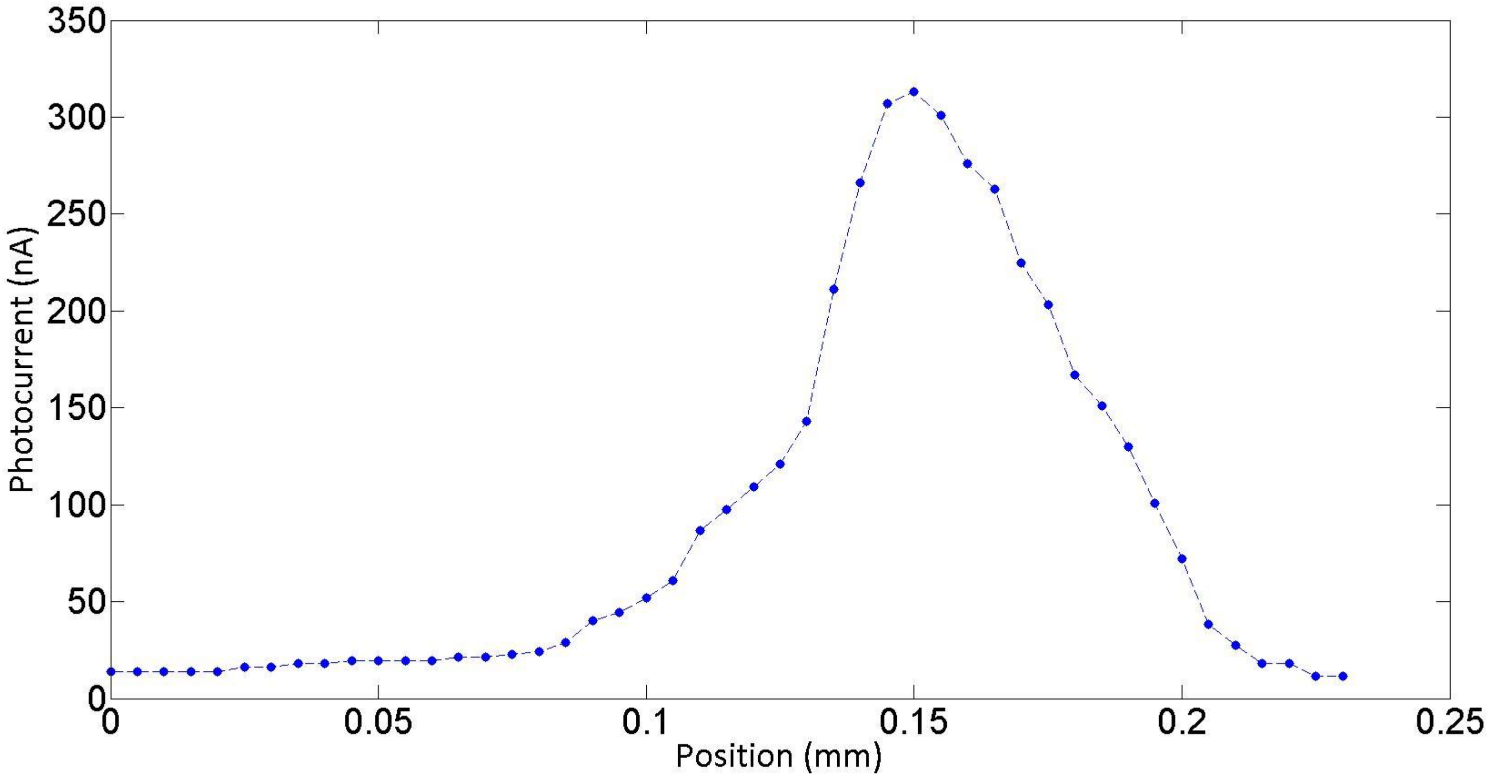



Laser Source
Optical Chopper
f = -25 mm
f = 500 mm
10x
Au
P-type
Si
Cu
Lock-in Amplifier

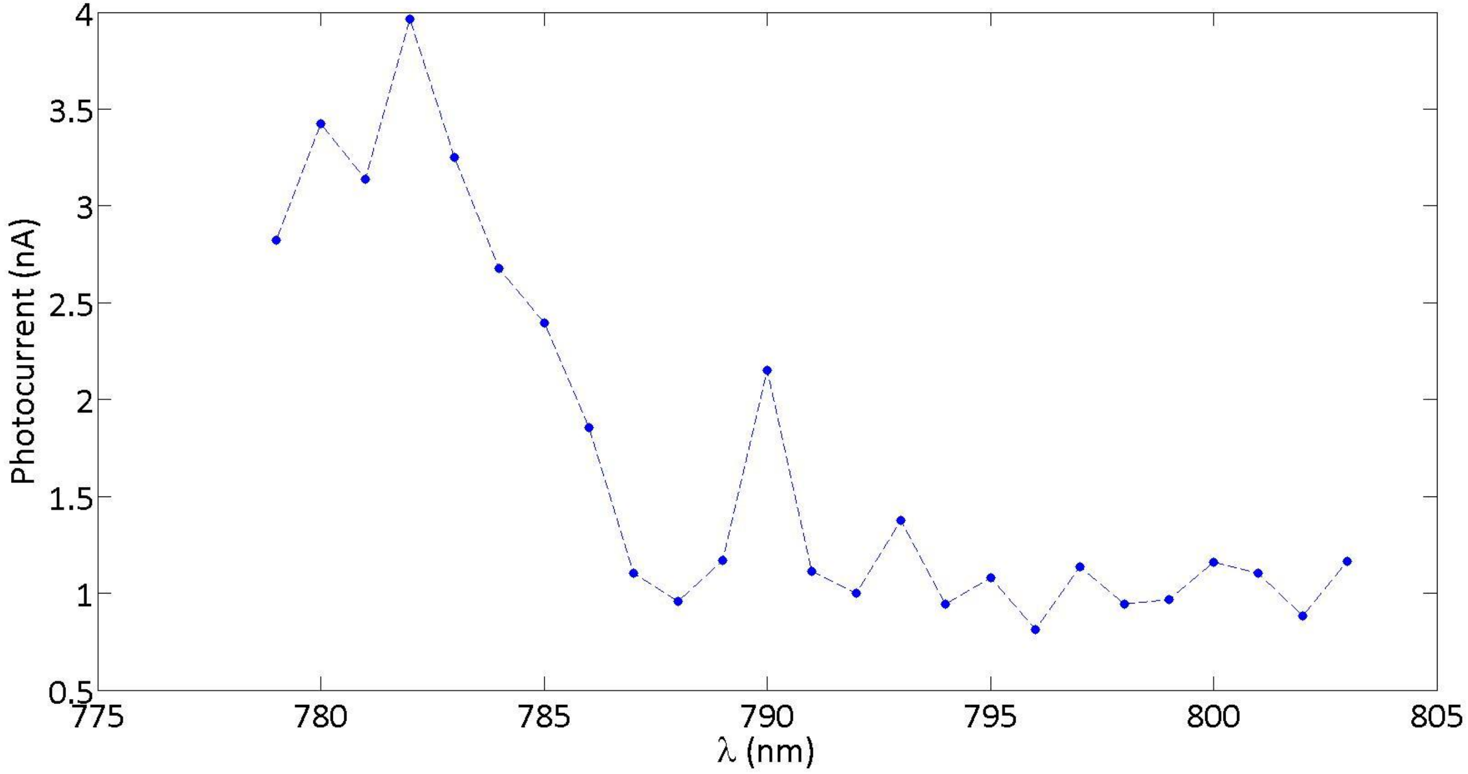
Photocurrent of Au-Si without Lock-in



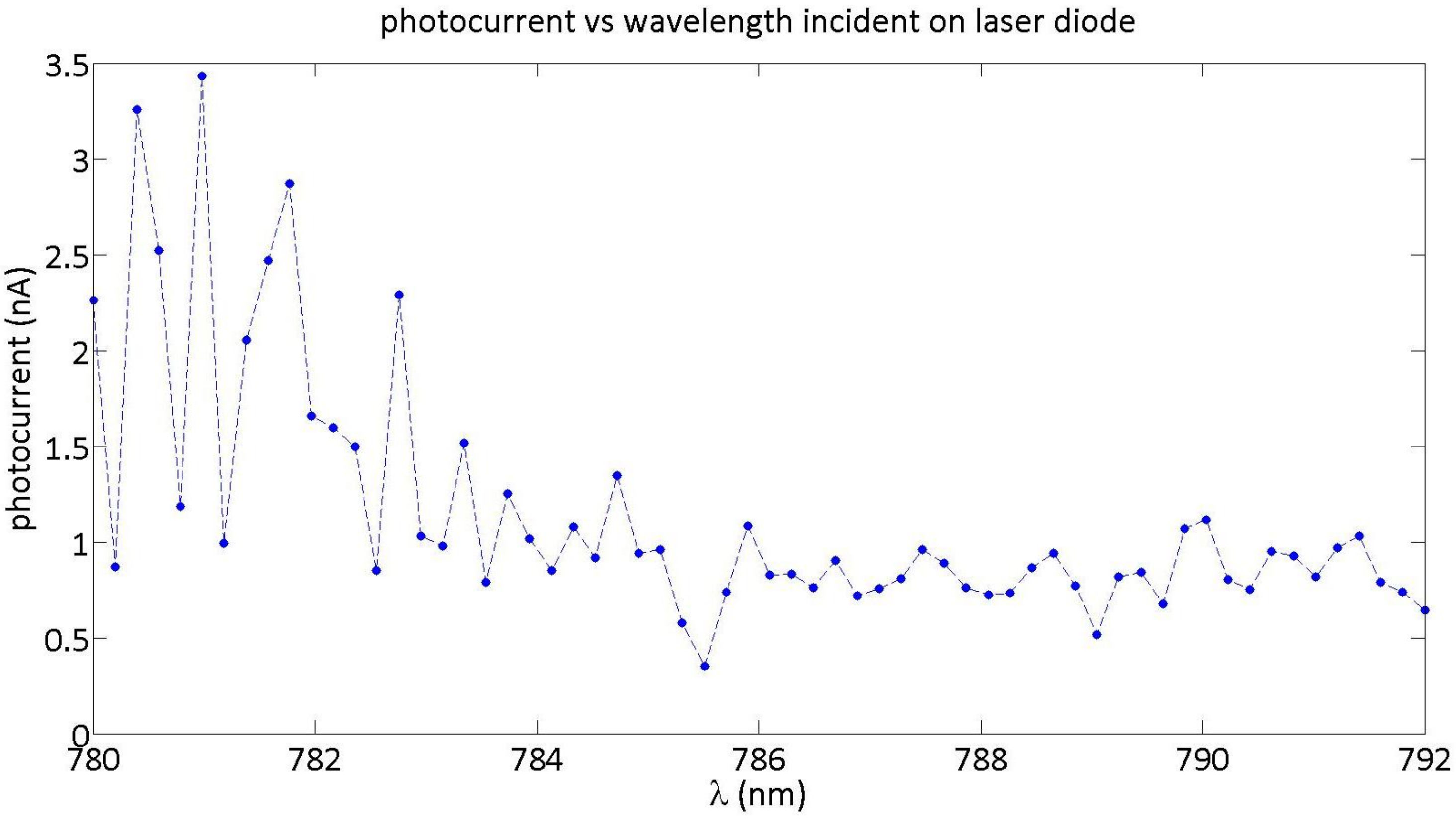
Photocurrent of AuSi with Lock-in



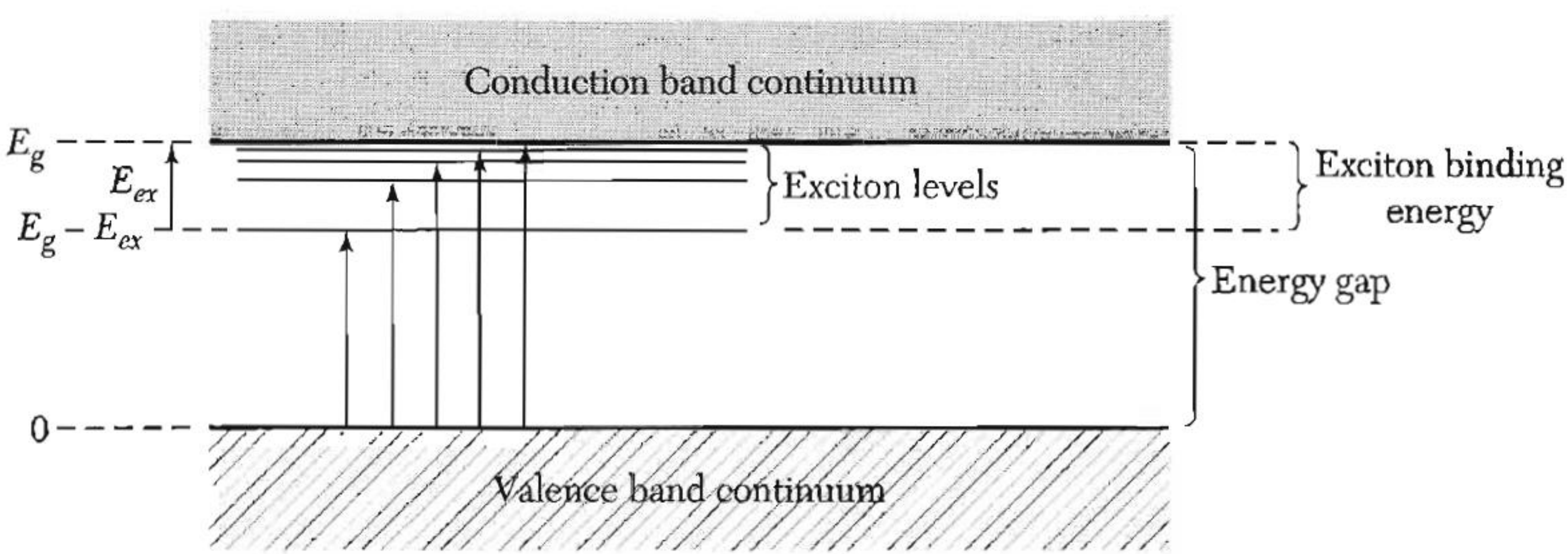
Photocurrent of LD with TDL



Photocurrent of LD with TDL



Exciton Levels



Future Work for Students

- Verify if excitons levels are present
- Automate the experiment in LabView
- Verify wavelength output in TDL
- Verify resistance of Schottky diode
- Obtain a Schottky diode with known characteristics

SEM Images

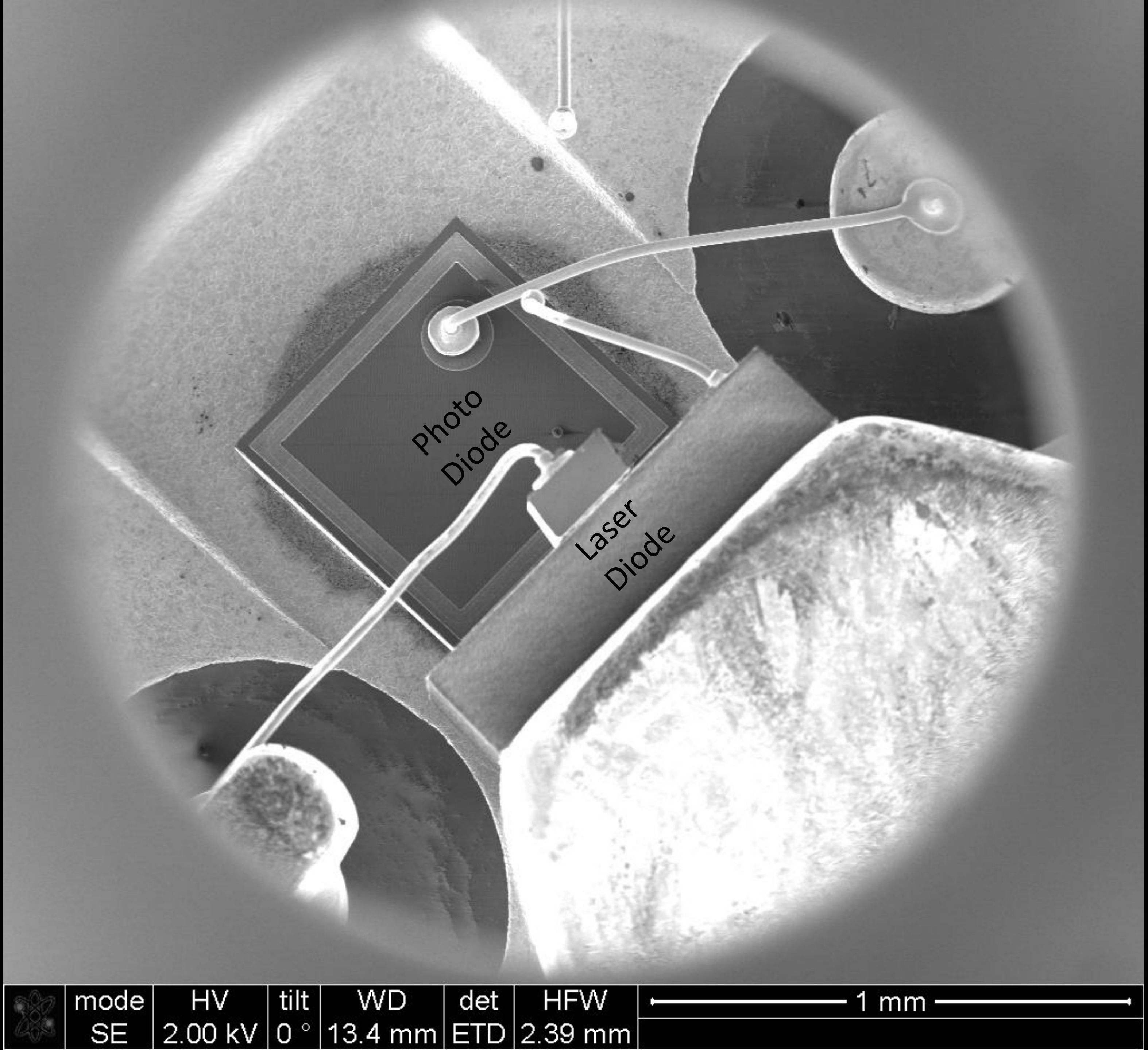
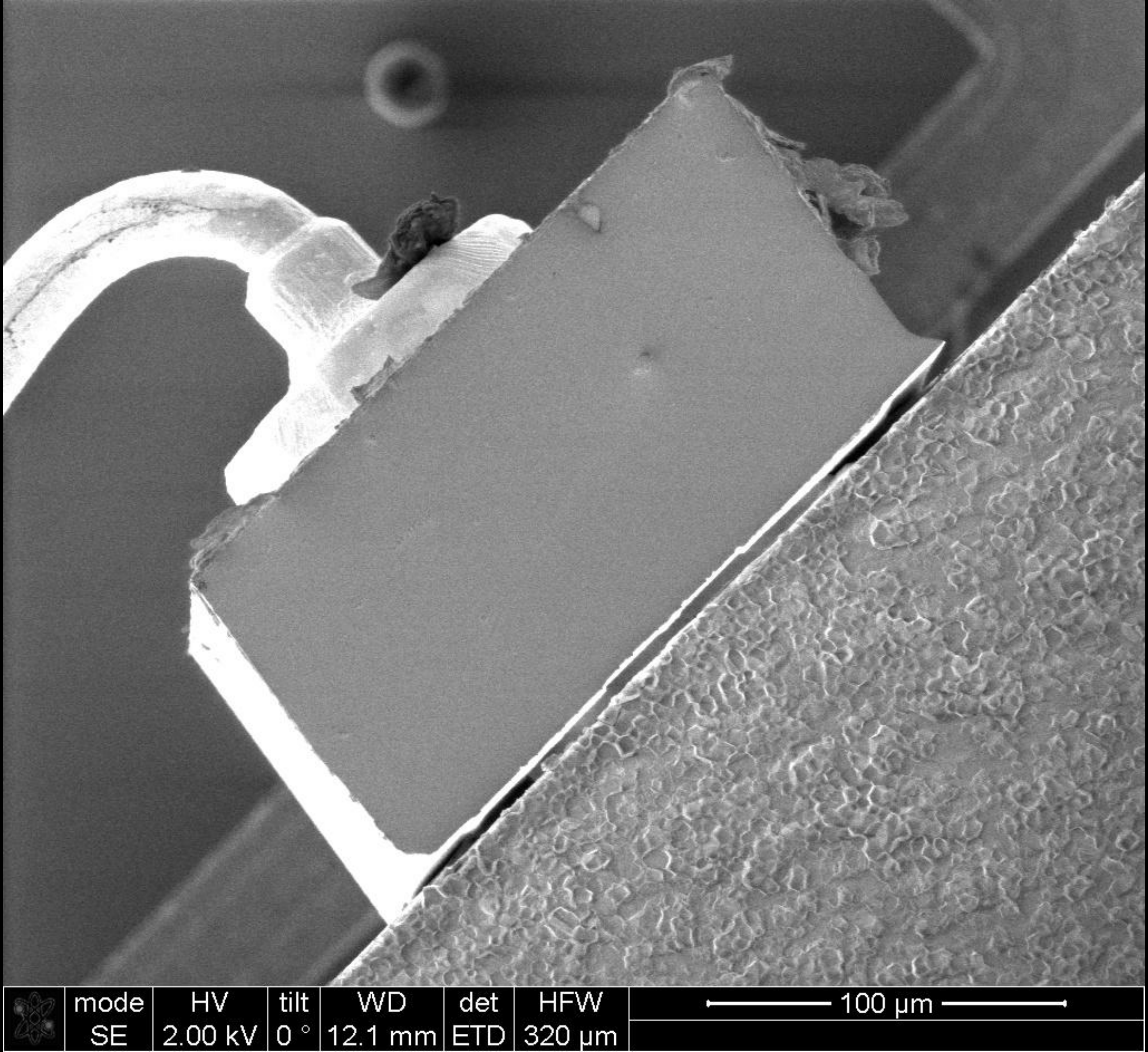
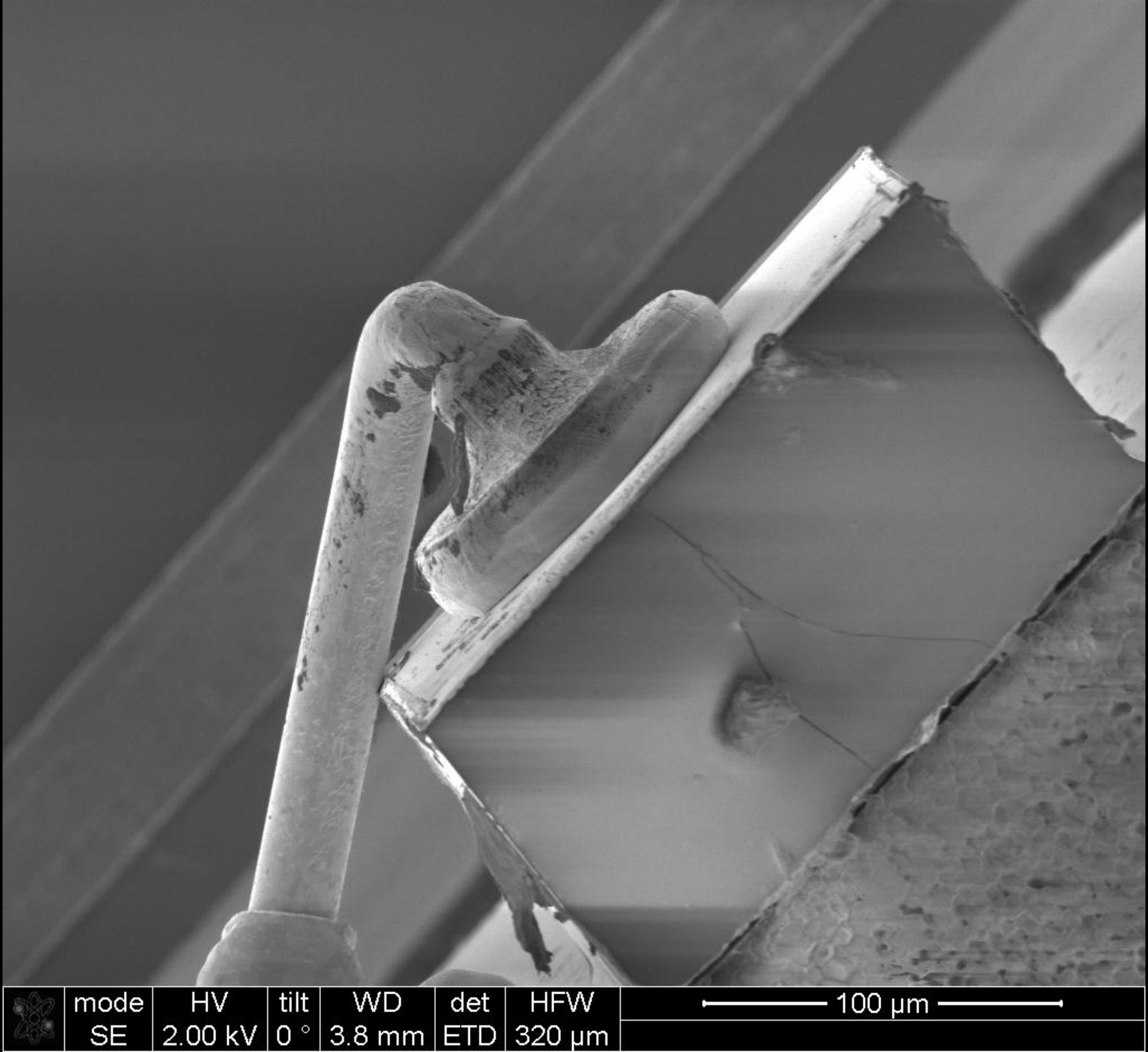
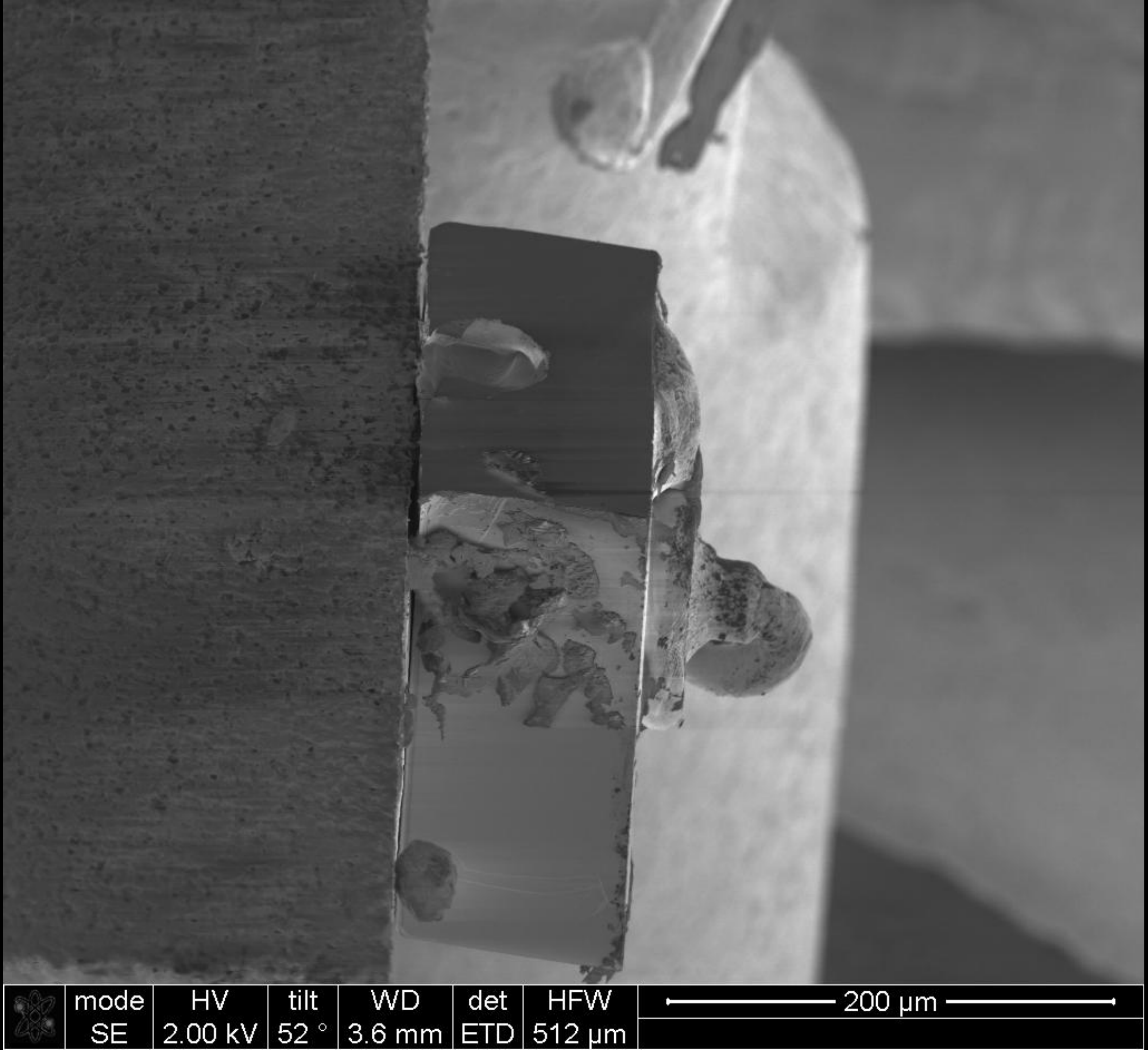


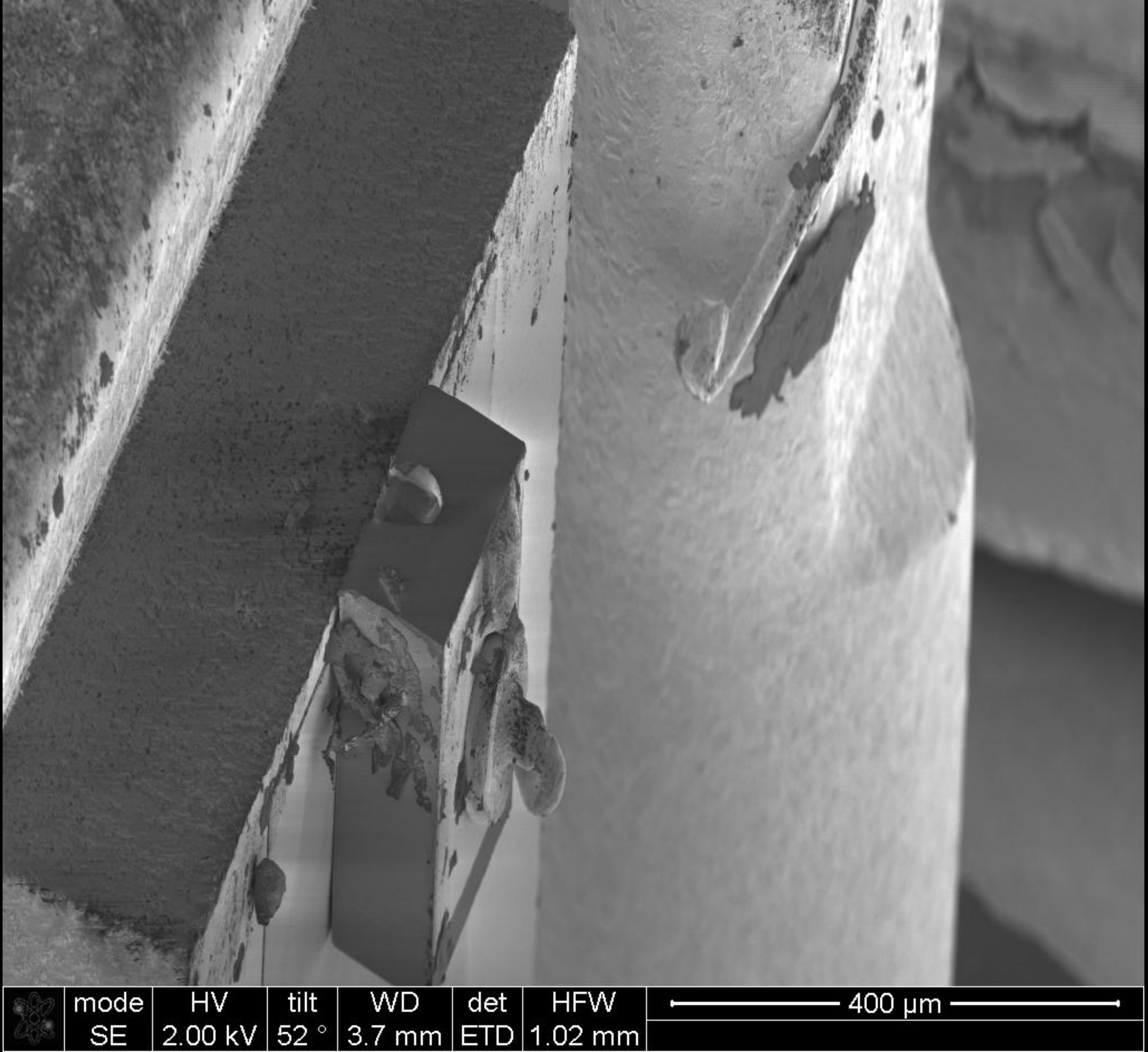
Photo
Diode
Laser
Diode
mode SE
HV 2.00 kV
tilt 0 °
WD 13.4 mm
det ETD
HFW 2.39 mm
1 mm

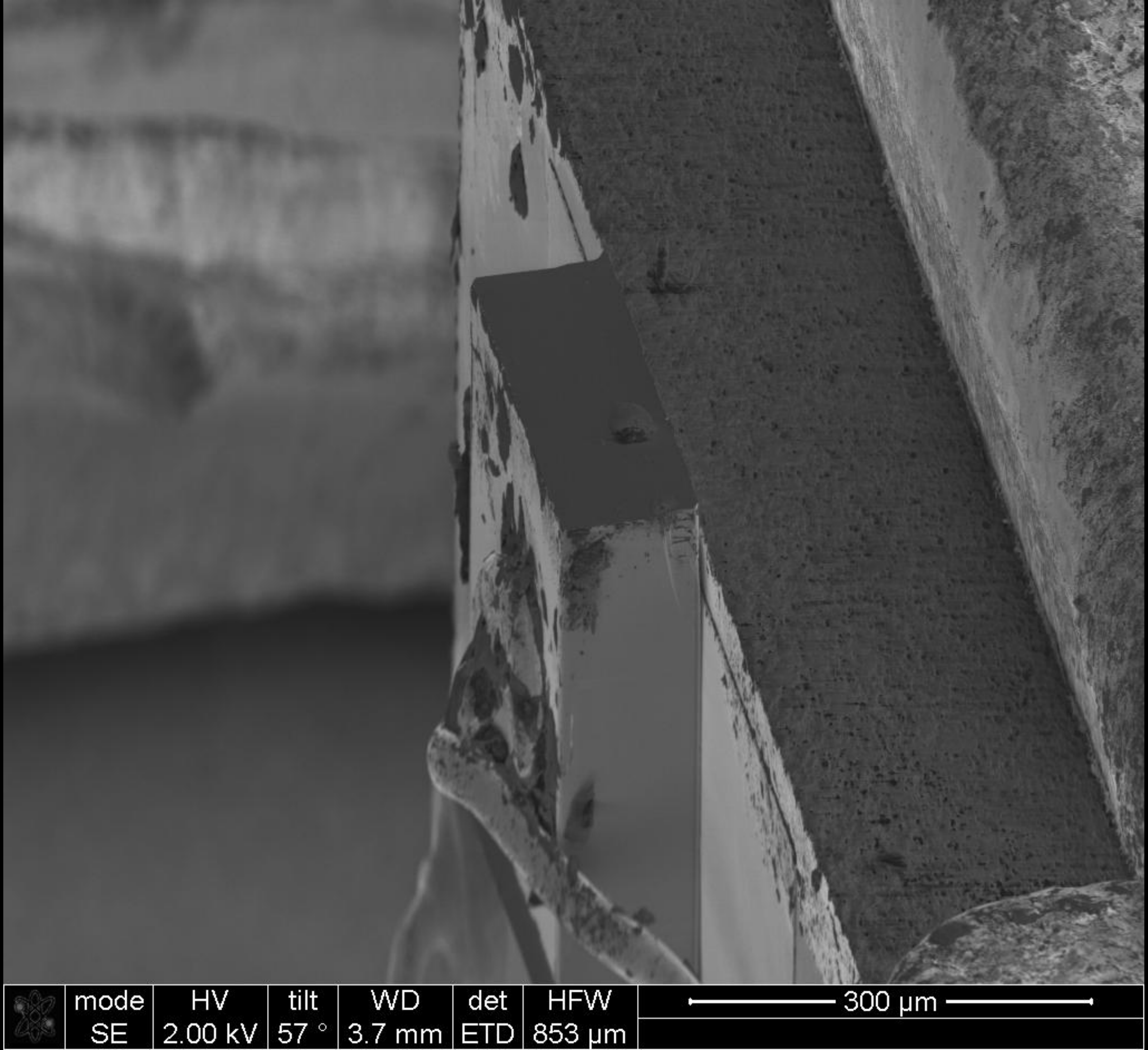


mode
SE
HV
2.00 kV
tilt
0 °
WD
12.1 mm
det
ETD
HFW
320 µm
100 µm

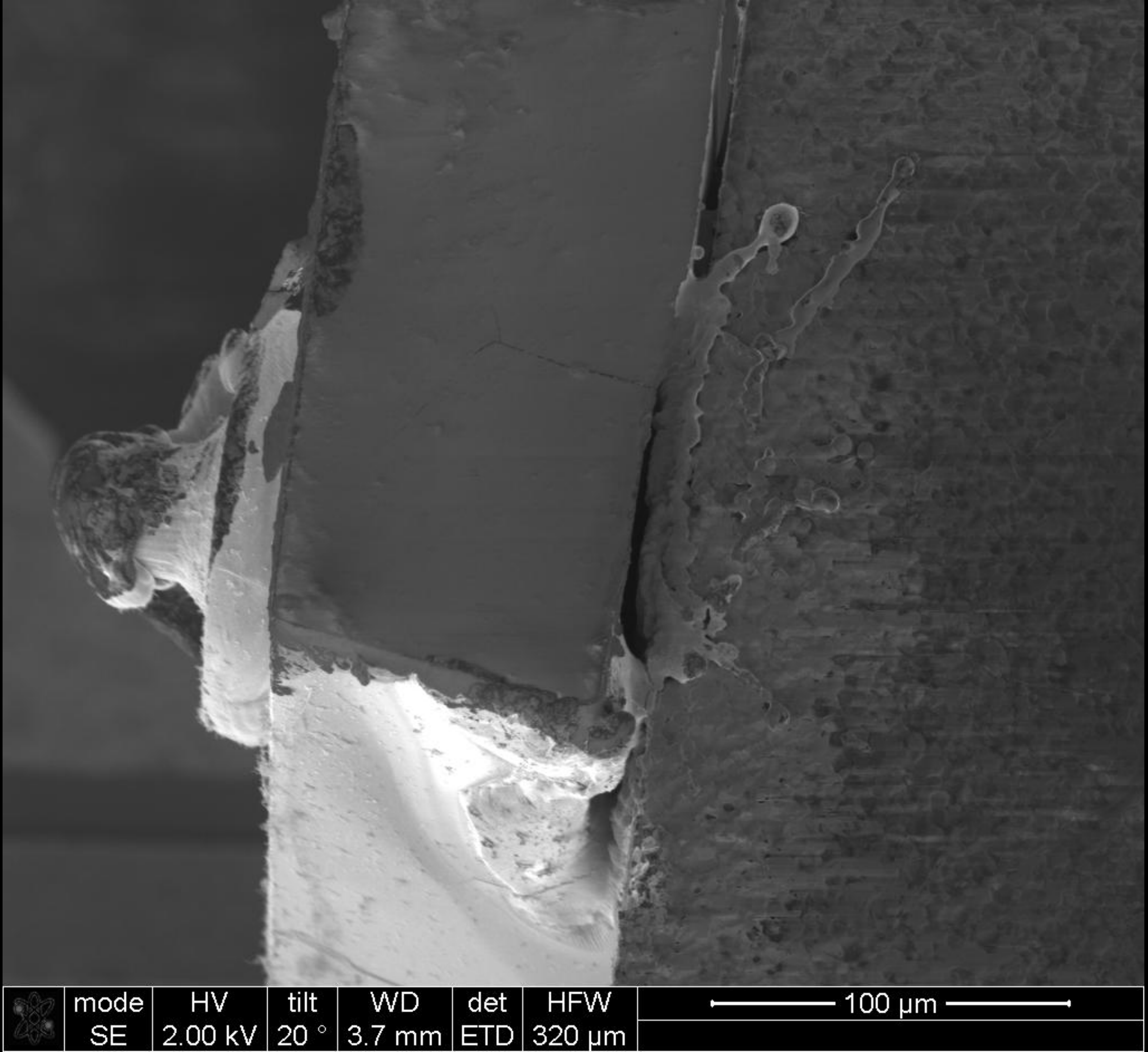

mode
SE
HV
2.00 kV
tilt
0 °
WD
3.8 mm
det
ETD
HFW
320 µm
100 µm

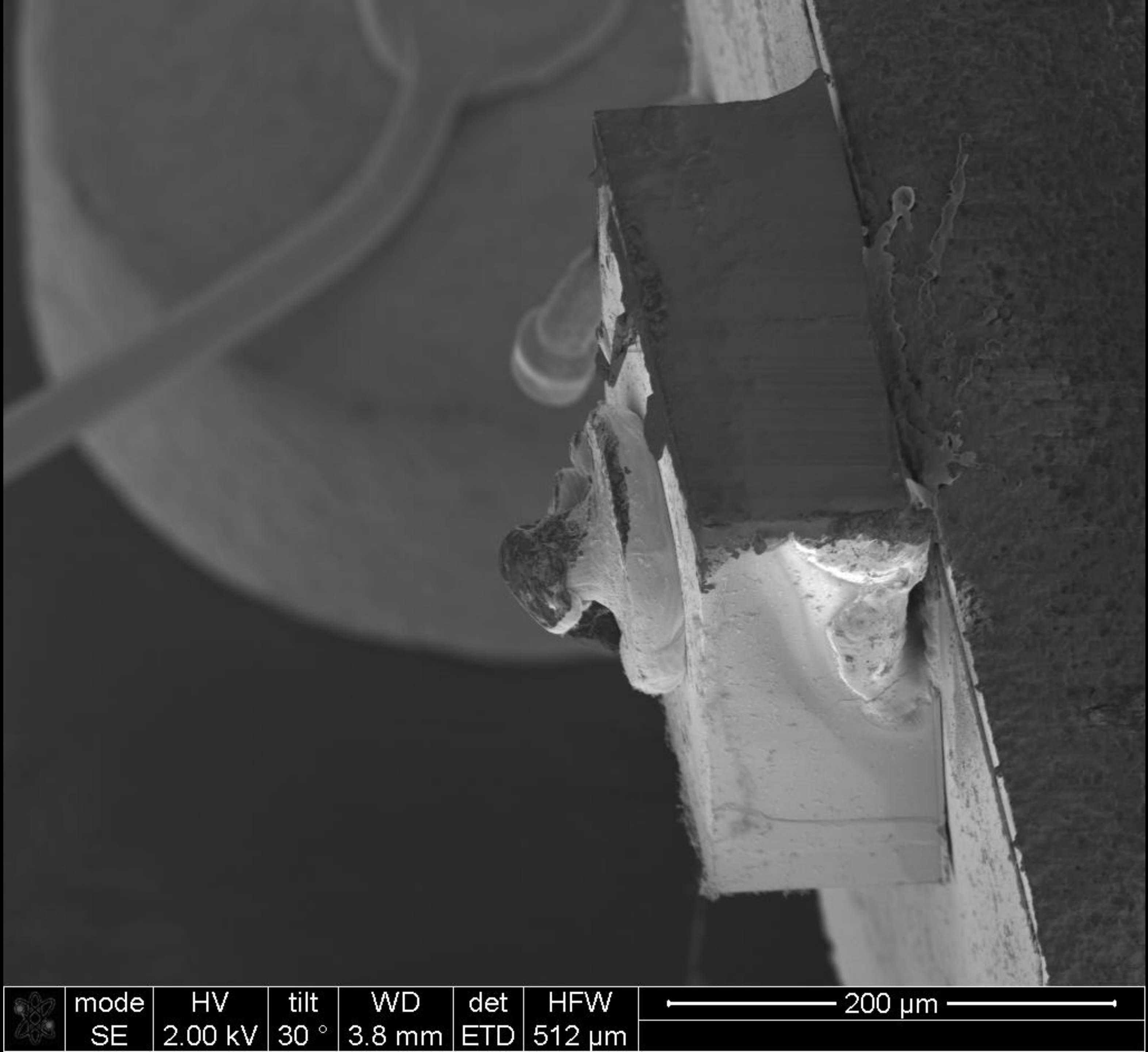

mode
SE
HV
2.00 kV
tilt
52 °
WD
3.6 mm
det
ETD
HFW
512 µm
200 µm

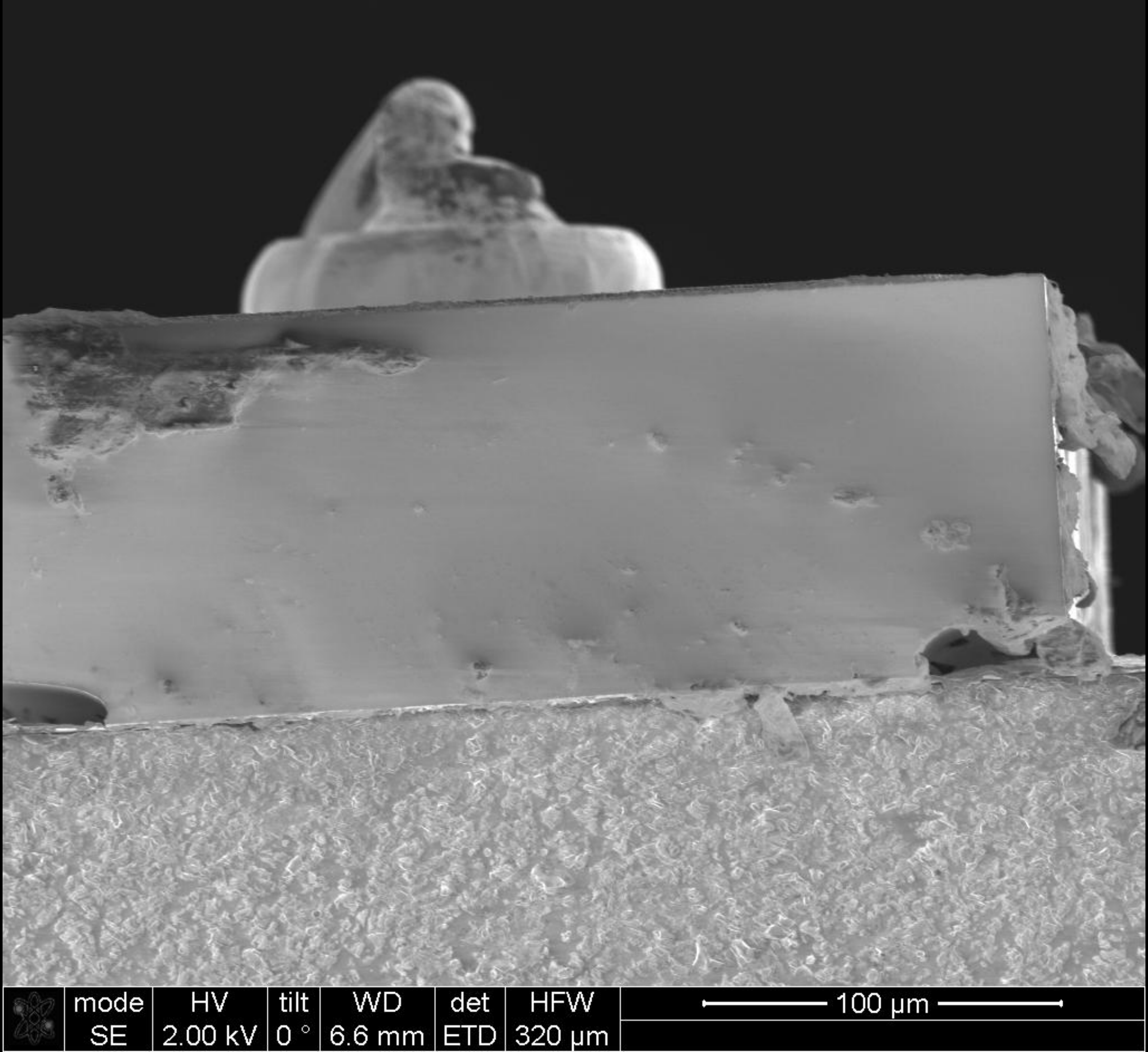

mode SE
HV 2.00 kV
tilt 52 °
WD 3.7 mm
det ETD
HFW 1.02 mm
400 µm



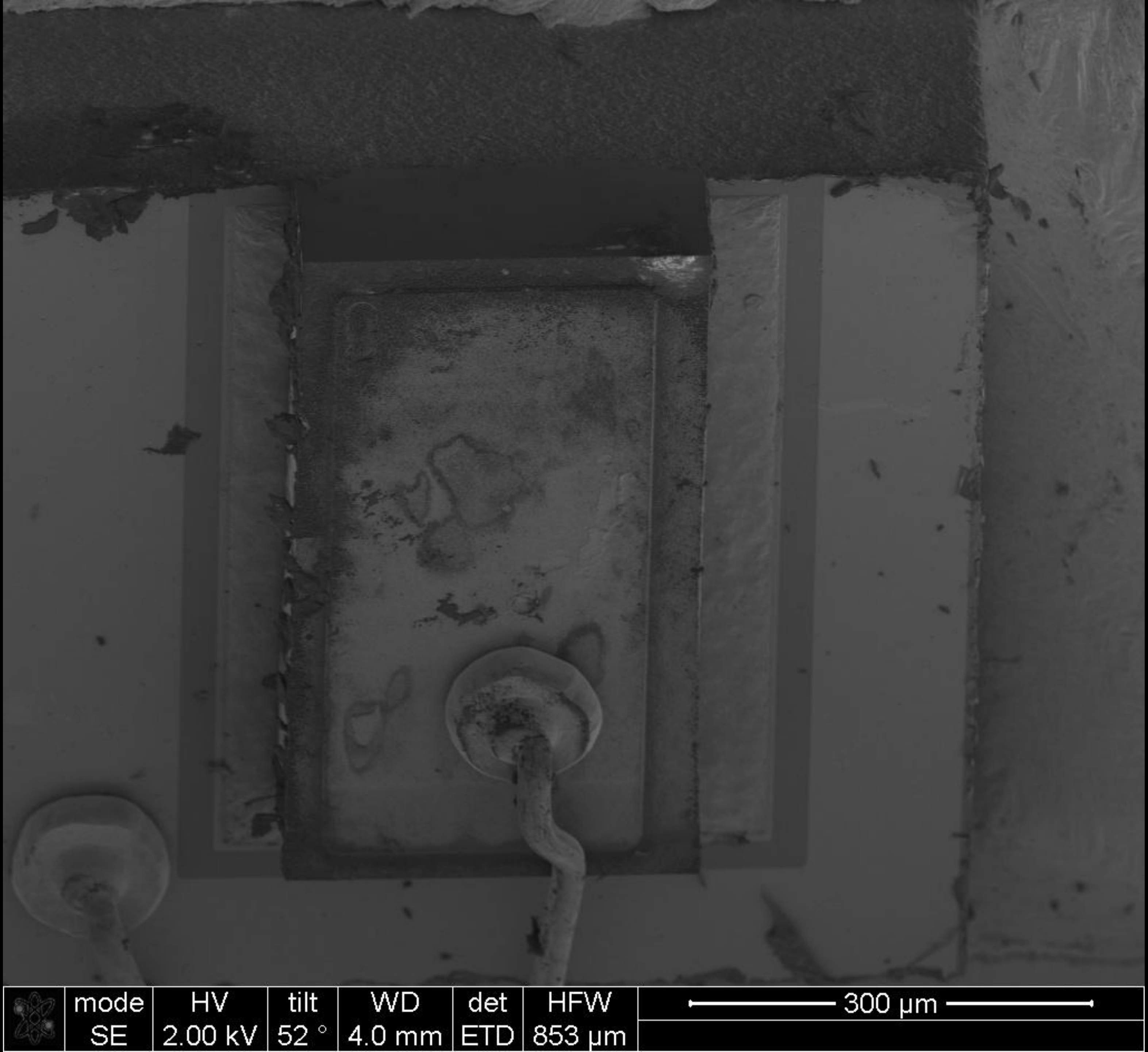
mode
SE
HV
2.00 kV
tilt
57 °
WD
3.7 mm
det
ETD
HFW
853 μm
300 μm

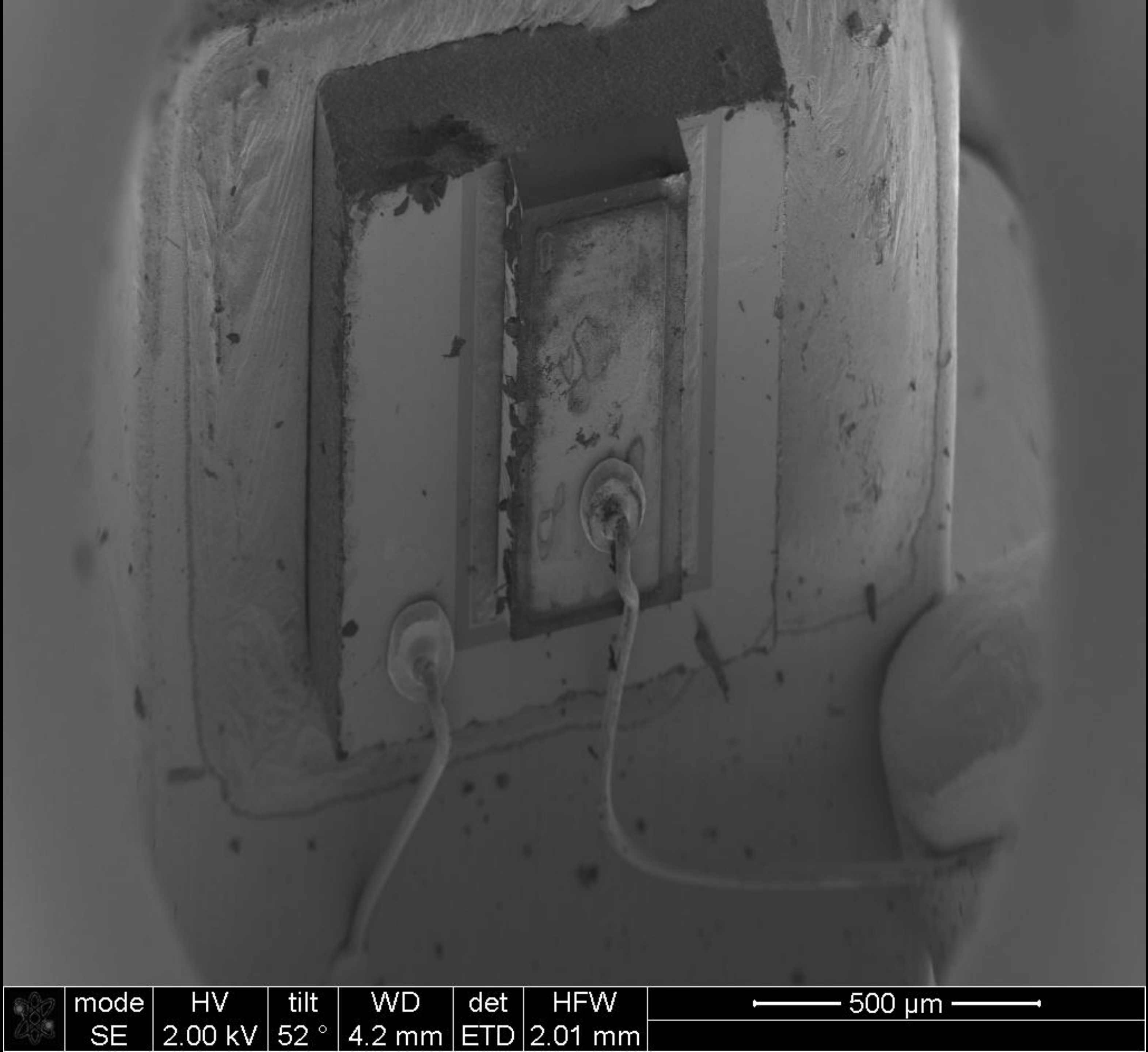

mode
SE
HV
2.00 kV
tilt
20 °
WD
3.7 mm
det
ETD
HFW
320 µm
100 µm

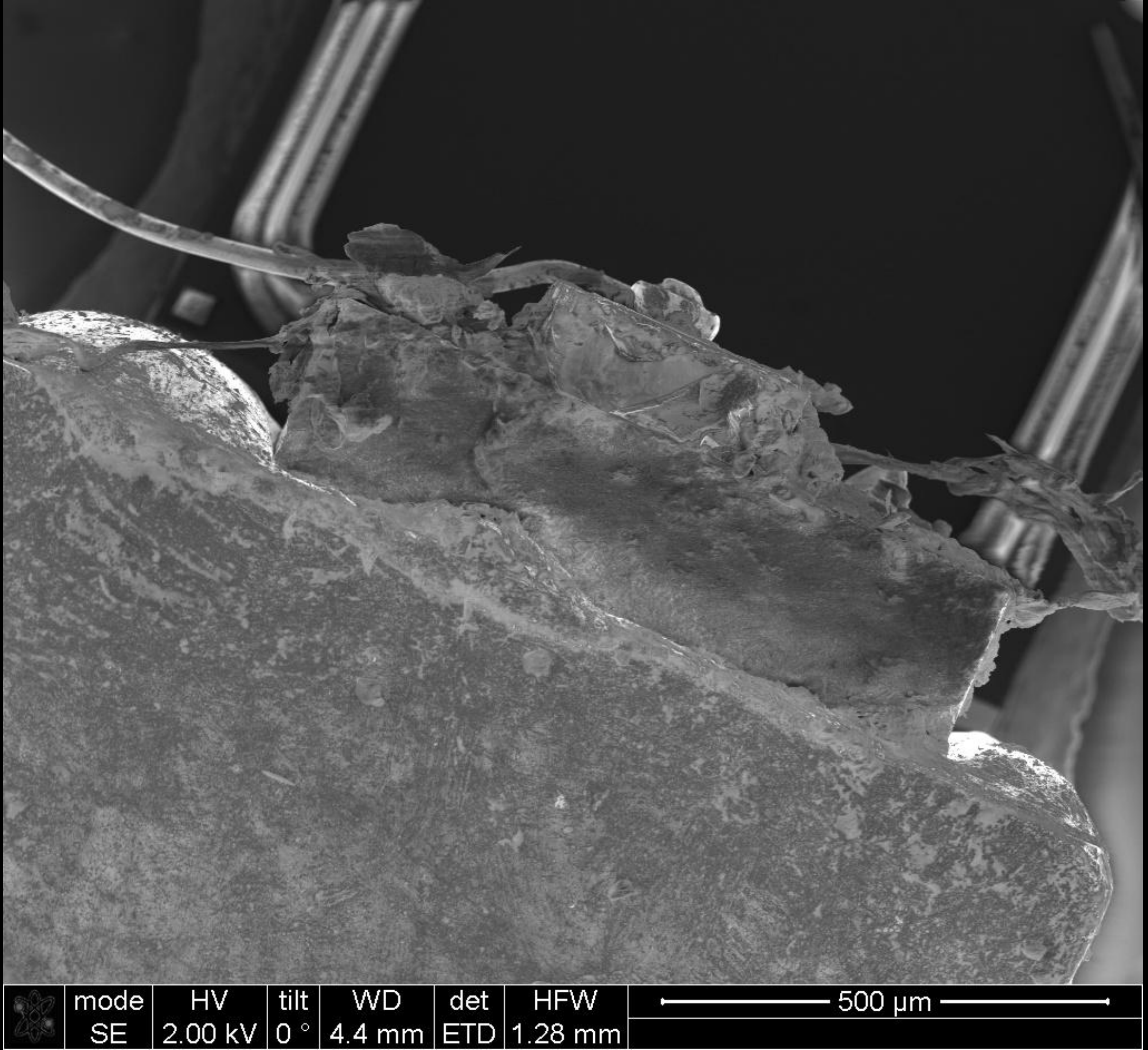

mode
SE
HV
2.00 kV
tilt
30 °
WD
3.8 mm
det
ETD
HFW
512 μm
200 μm

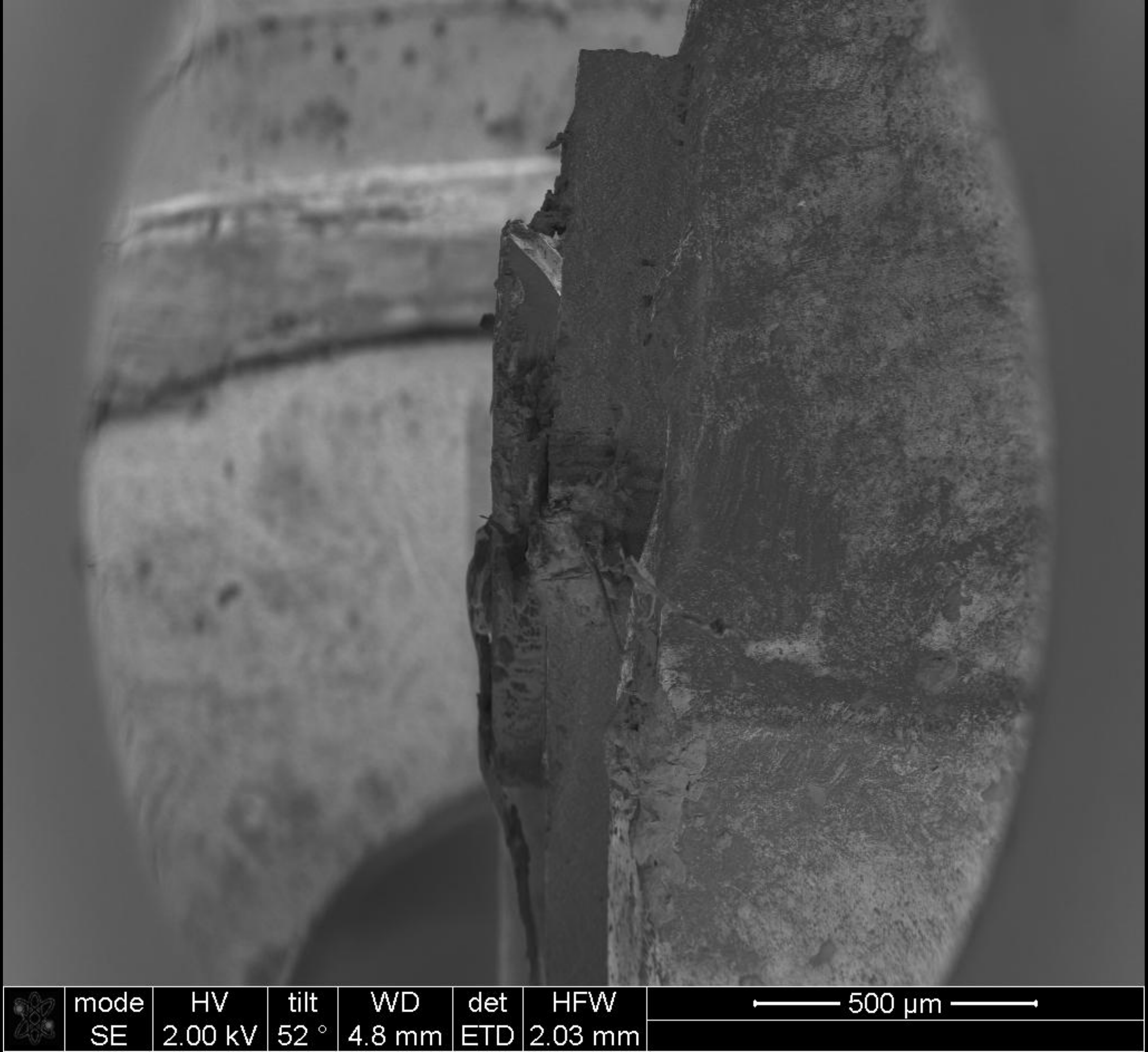


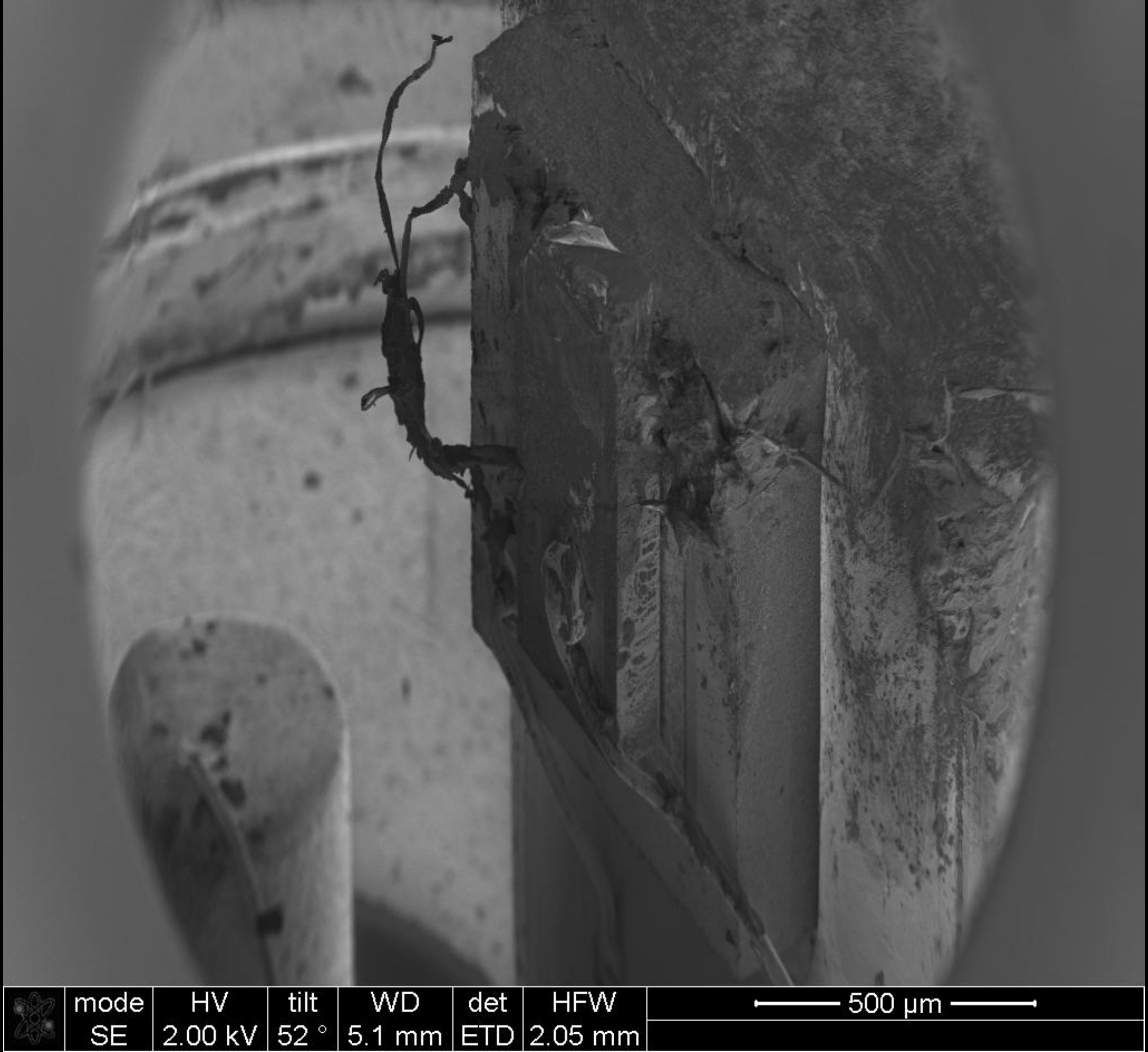
mode
SE
HV
2.00 kV
tilt
0 °
WD
6.6 mm
det
ETD
HFW
320 µm
100 µm

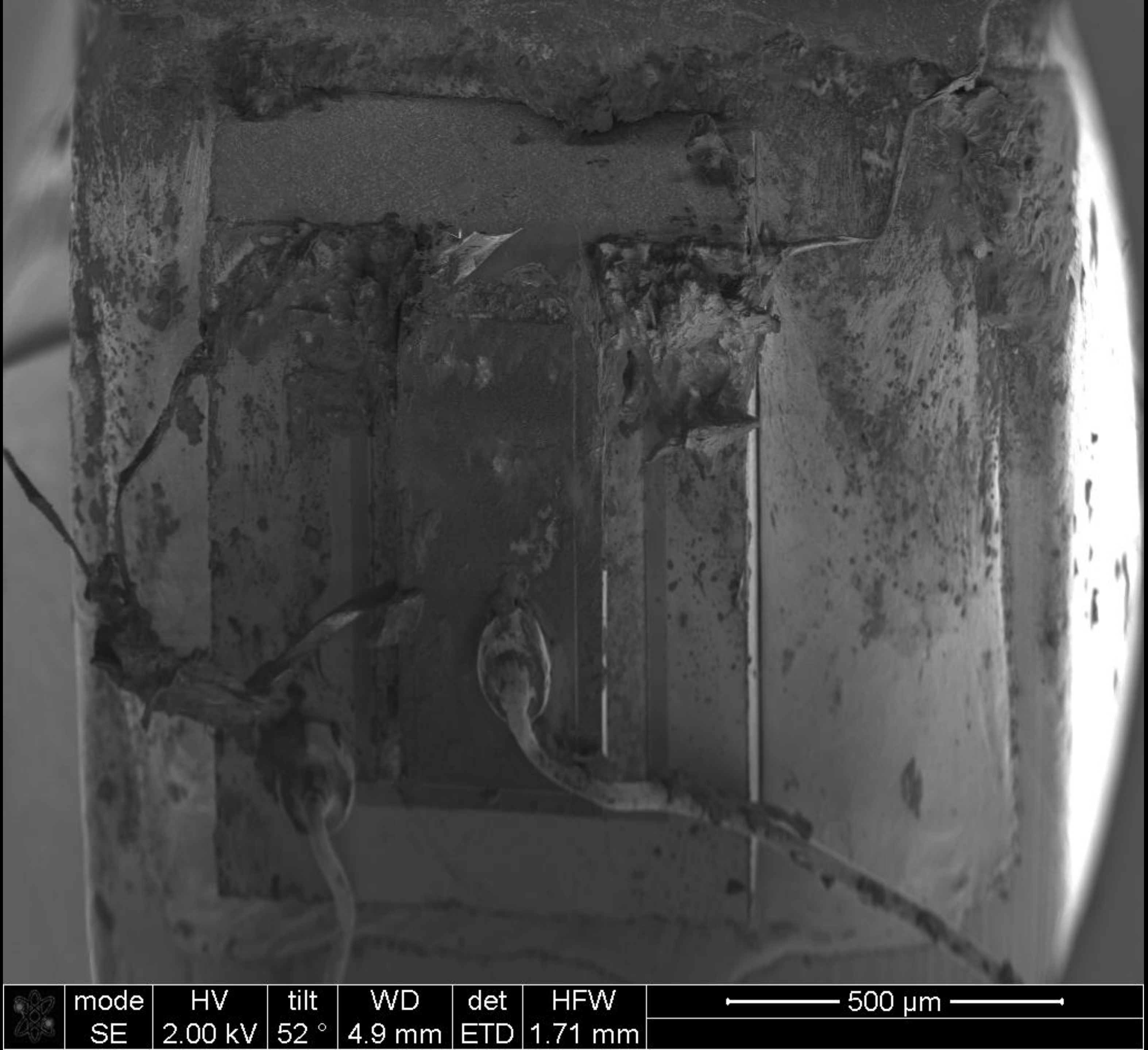

mode SE
HV 2.00 kV
tilt 52 °
WD 4.0 mm
det ETD
HFW 853 µm
300 µm

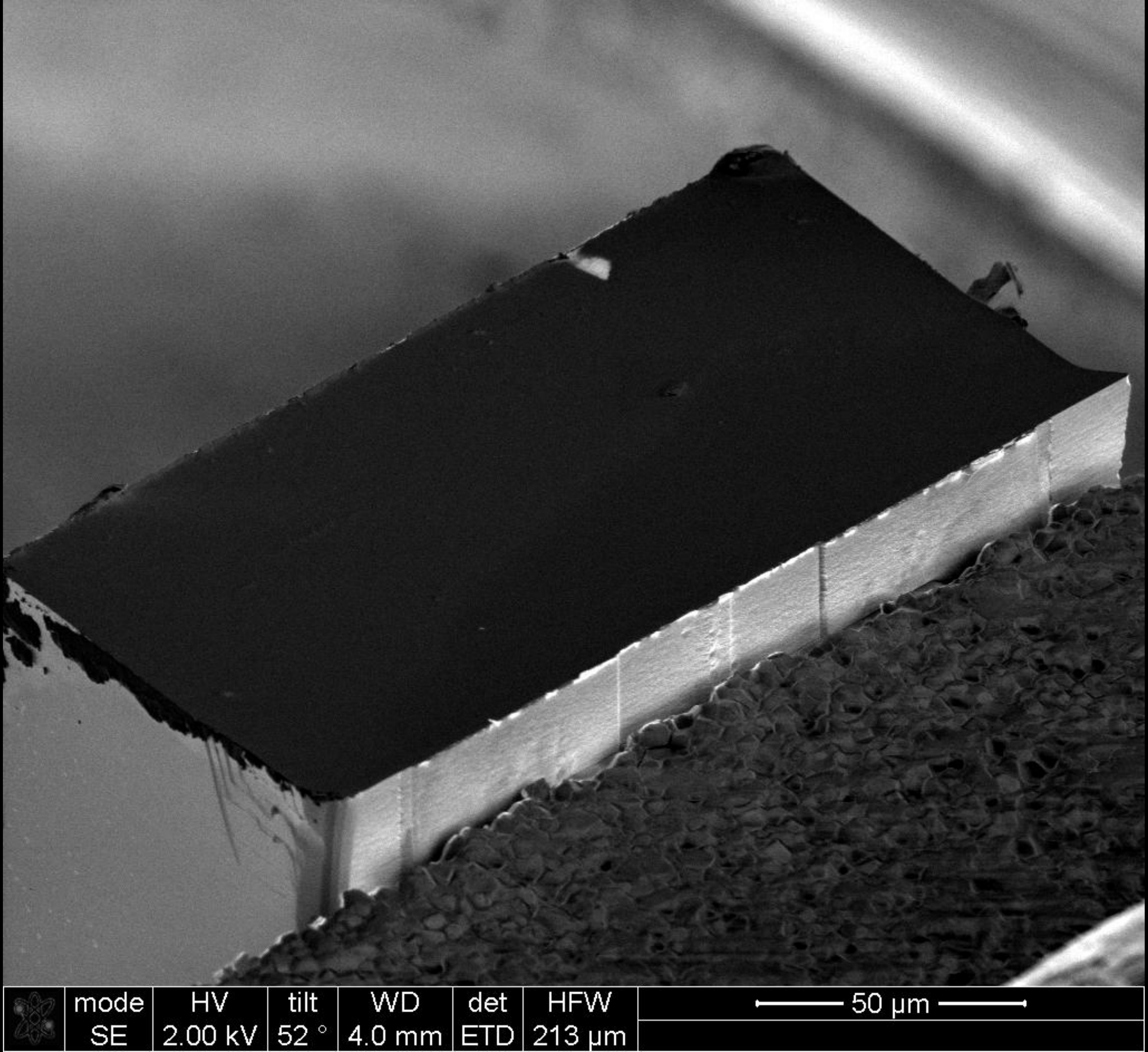

mode
SE
HV
2.00 kV
tilt
52 °
WD
4.2 mm
det
ETD
HFW
2.01 mm
500 µm

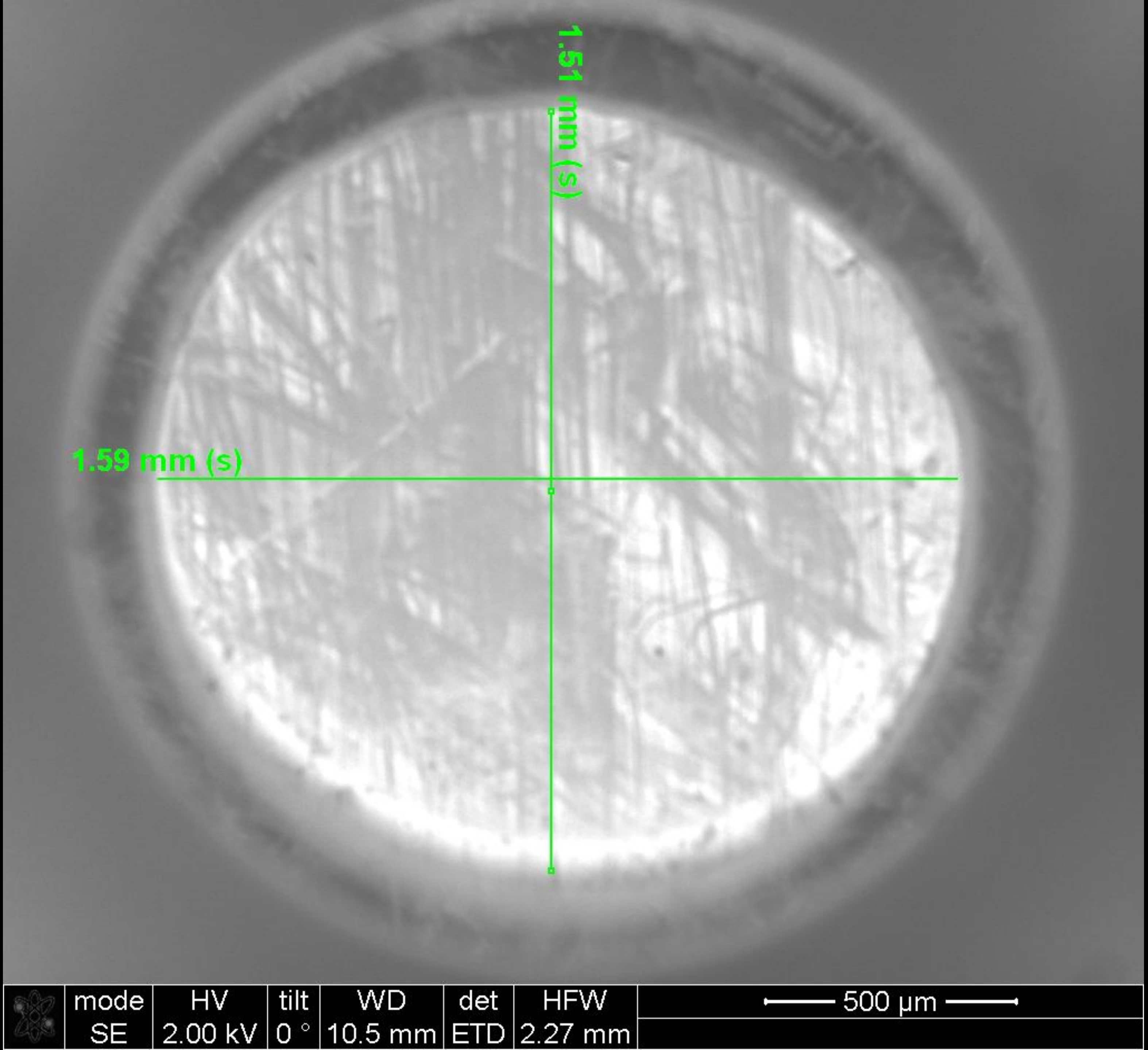

mode
SE
HV
2.00 kV
tilt
0 °
WD
4.4 mm
det
ETD
HFW
1.28 mm
500 µm

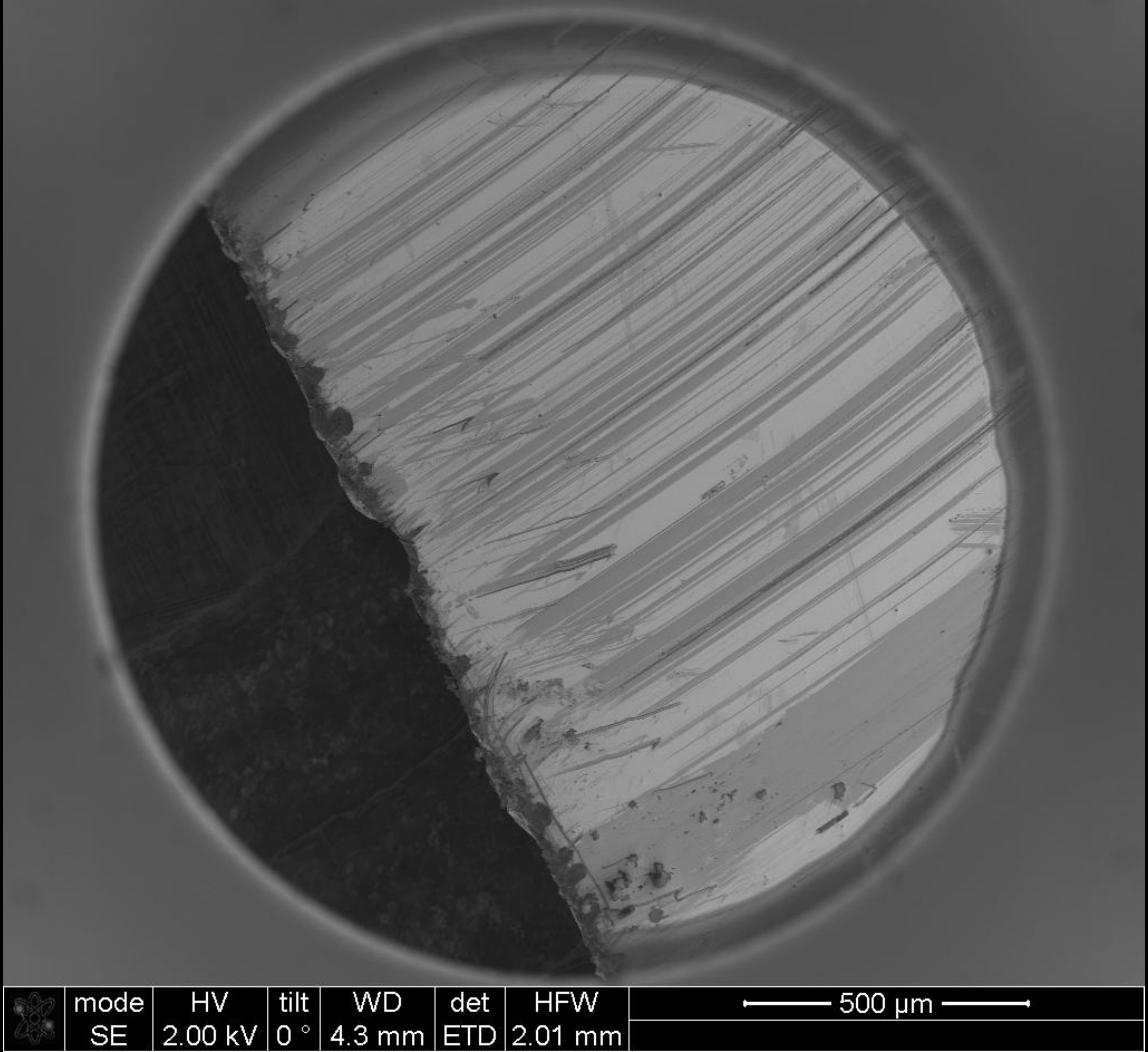

mode
SE
HV
2.00 kV
tilt
52 °
WD
4.8 mm
det
ETD
HFW
2.03 mm
500 µm


mode SE
HV 2.00 kV
tilt 52 °
WD 5.1 mm
det ETD
HFW 2.05 mm
500 μm

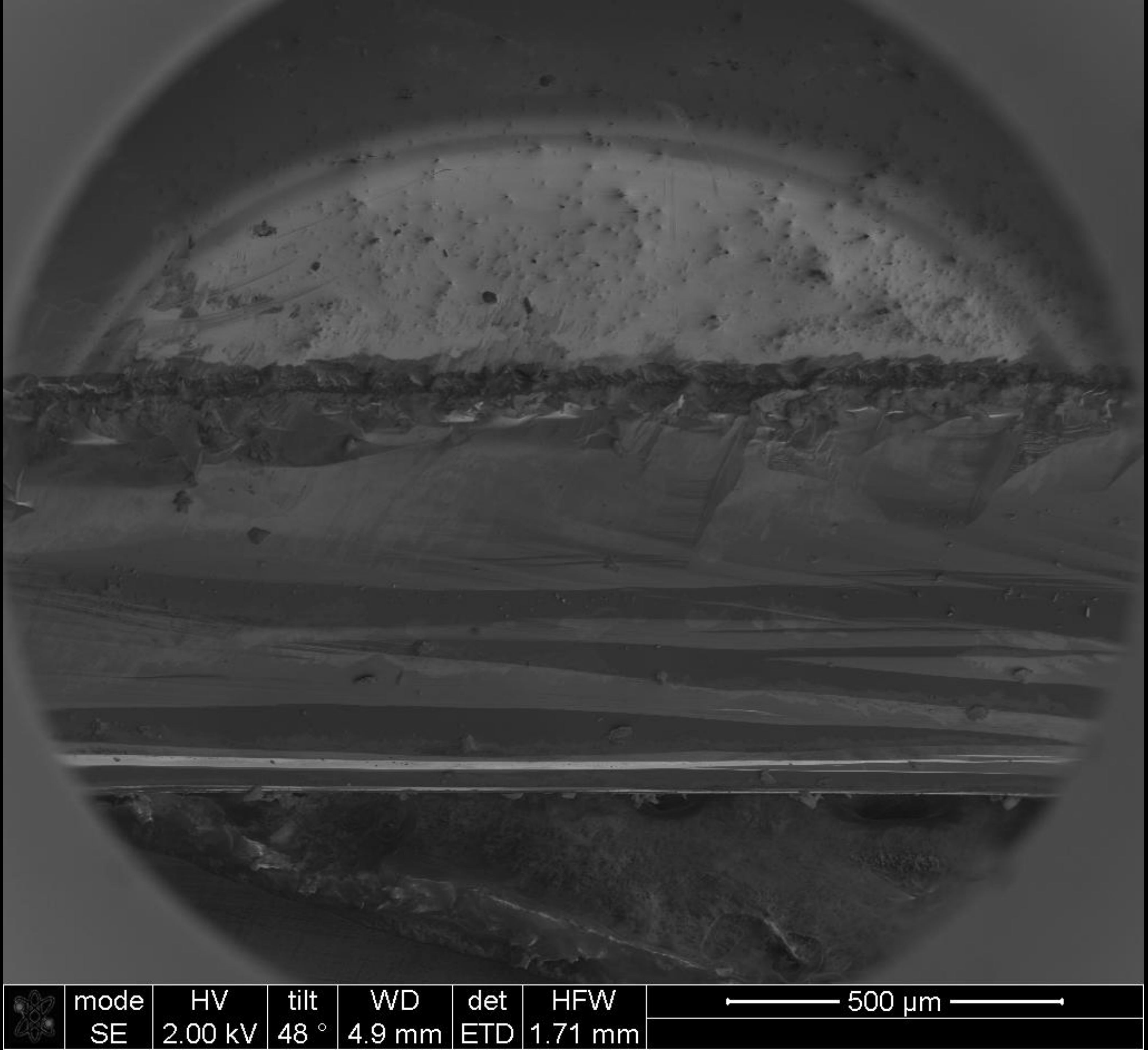

mode
SE
HV
2.00 kV
tilt
52 °
WD
4.9 mm
det
ETD
HFW
1.71 mm
500 µm

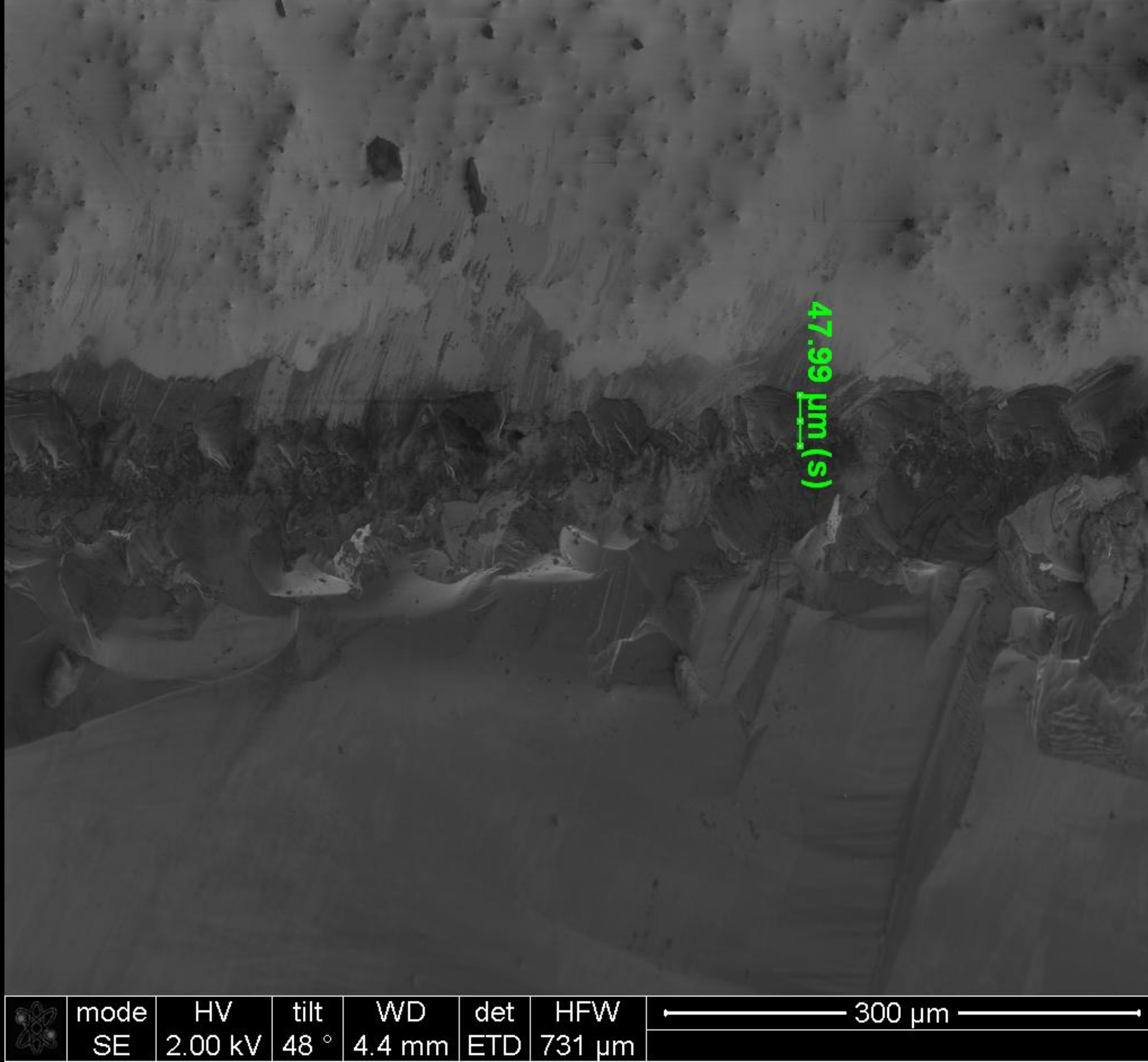

mode
SE
HV
2.00 kV
tilt
52 °
WD
4.0 mm
det
ETD
HFW
213 µm
50 µm

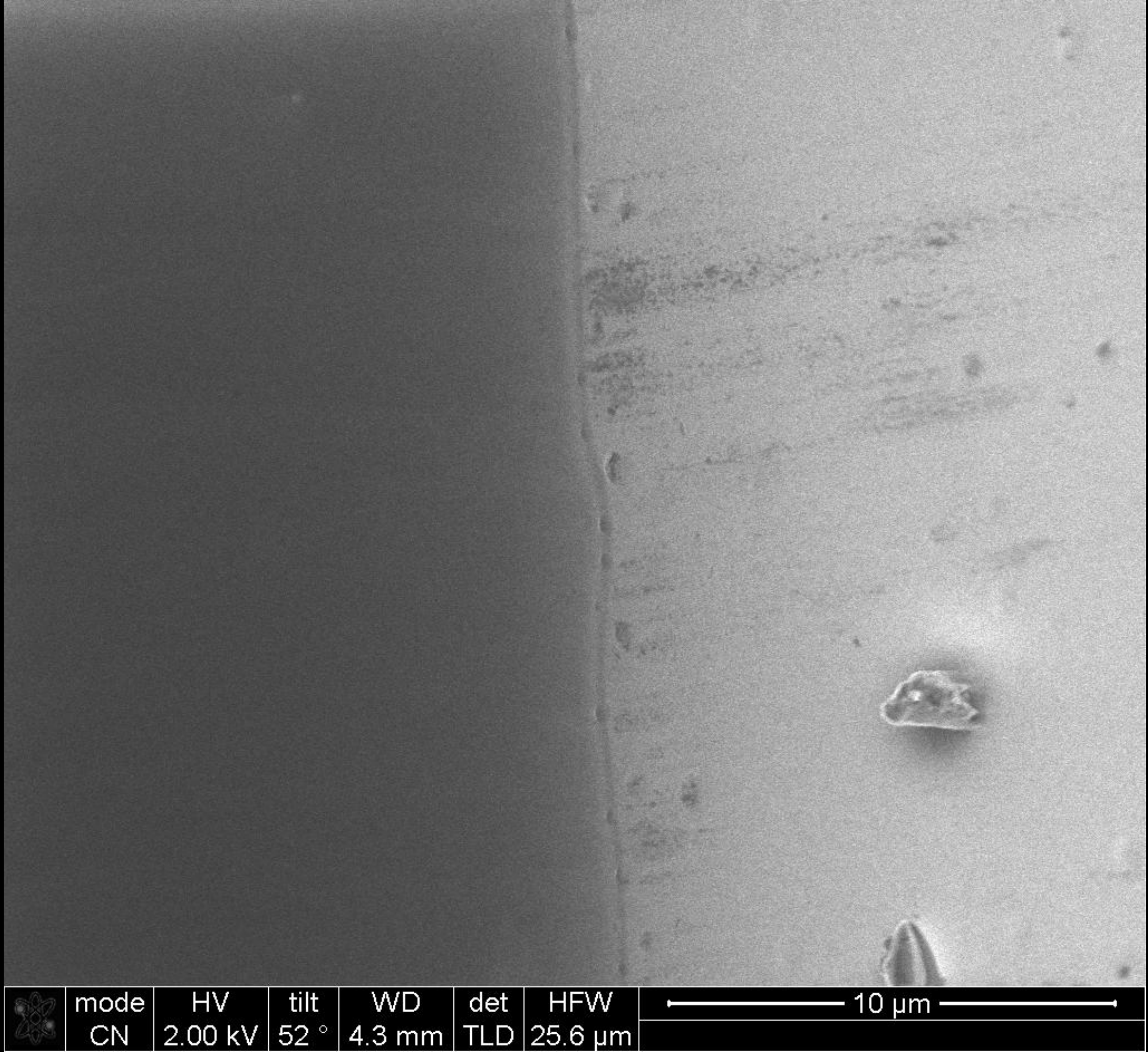

1.51 mm (s)
1.59 mm (s)
mode
SE
HV
2.00 kV
tilt
0 °
WD
10.5 mm
det
ETD
HFW
2.27 mm
500 µm

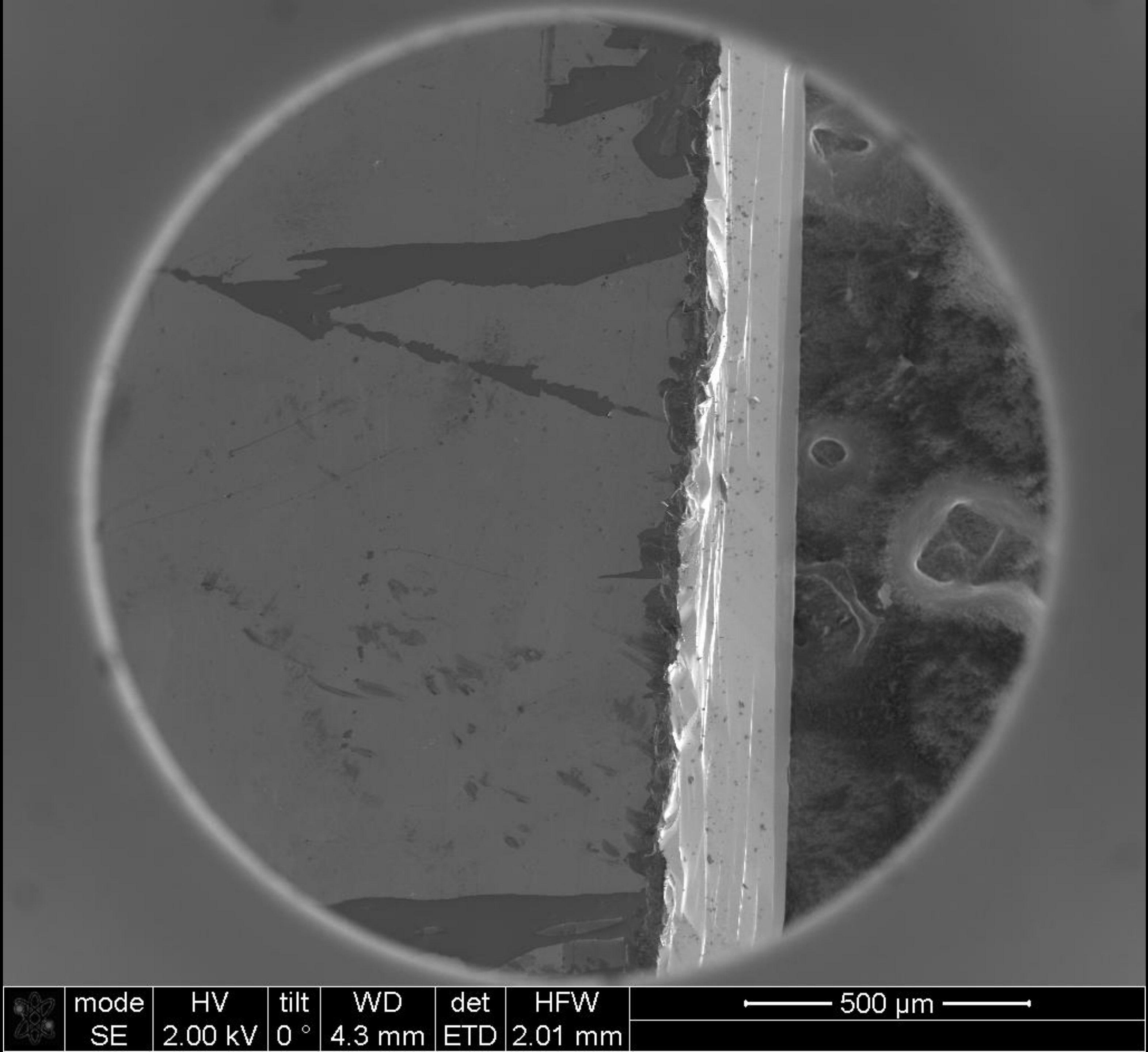


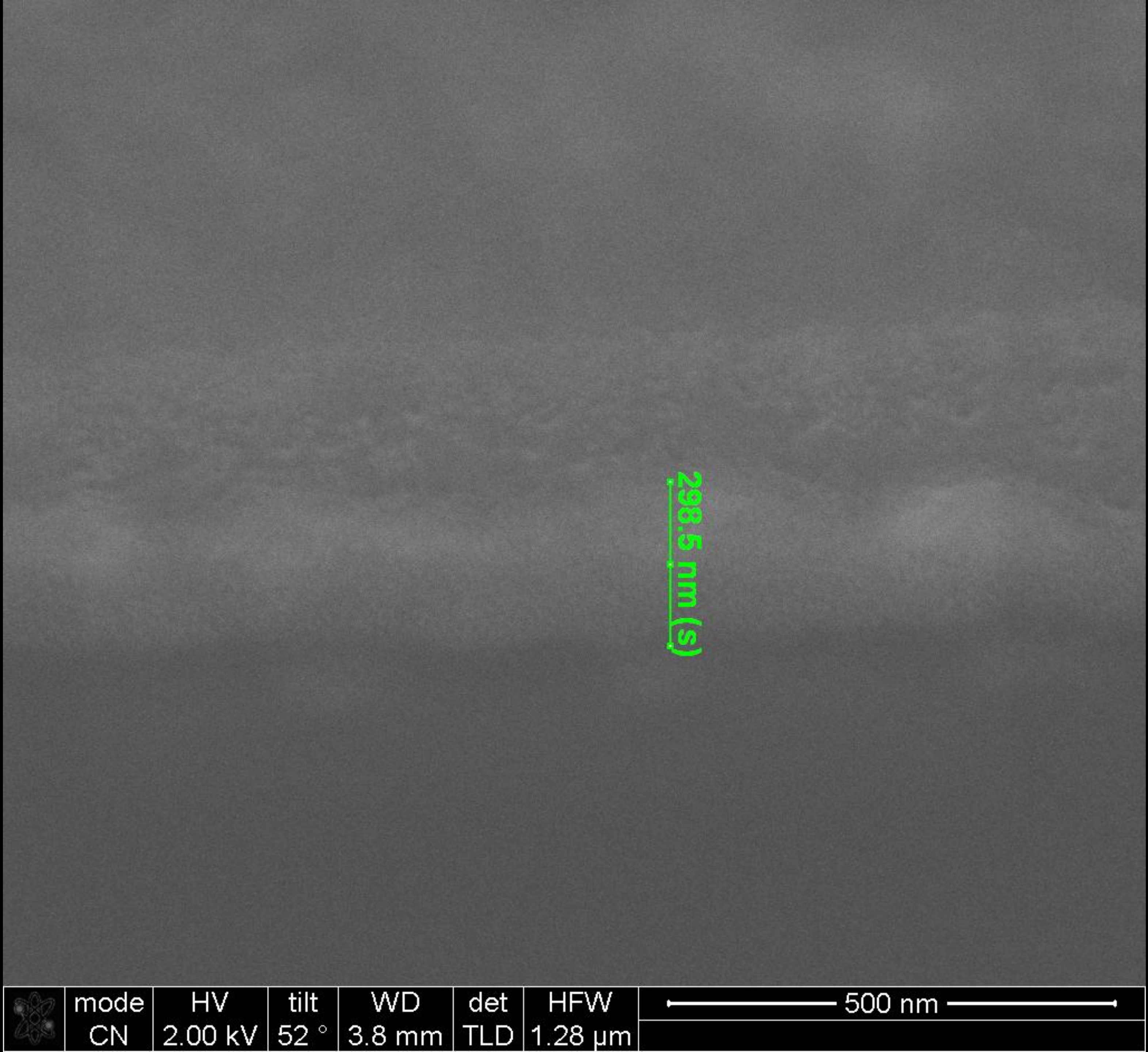
mode SE
HV 2.00 kV
tilt 0 °
WD 4.3 mm
det ETD
HFW 2.01 mm
500 µm

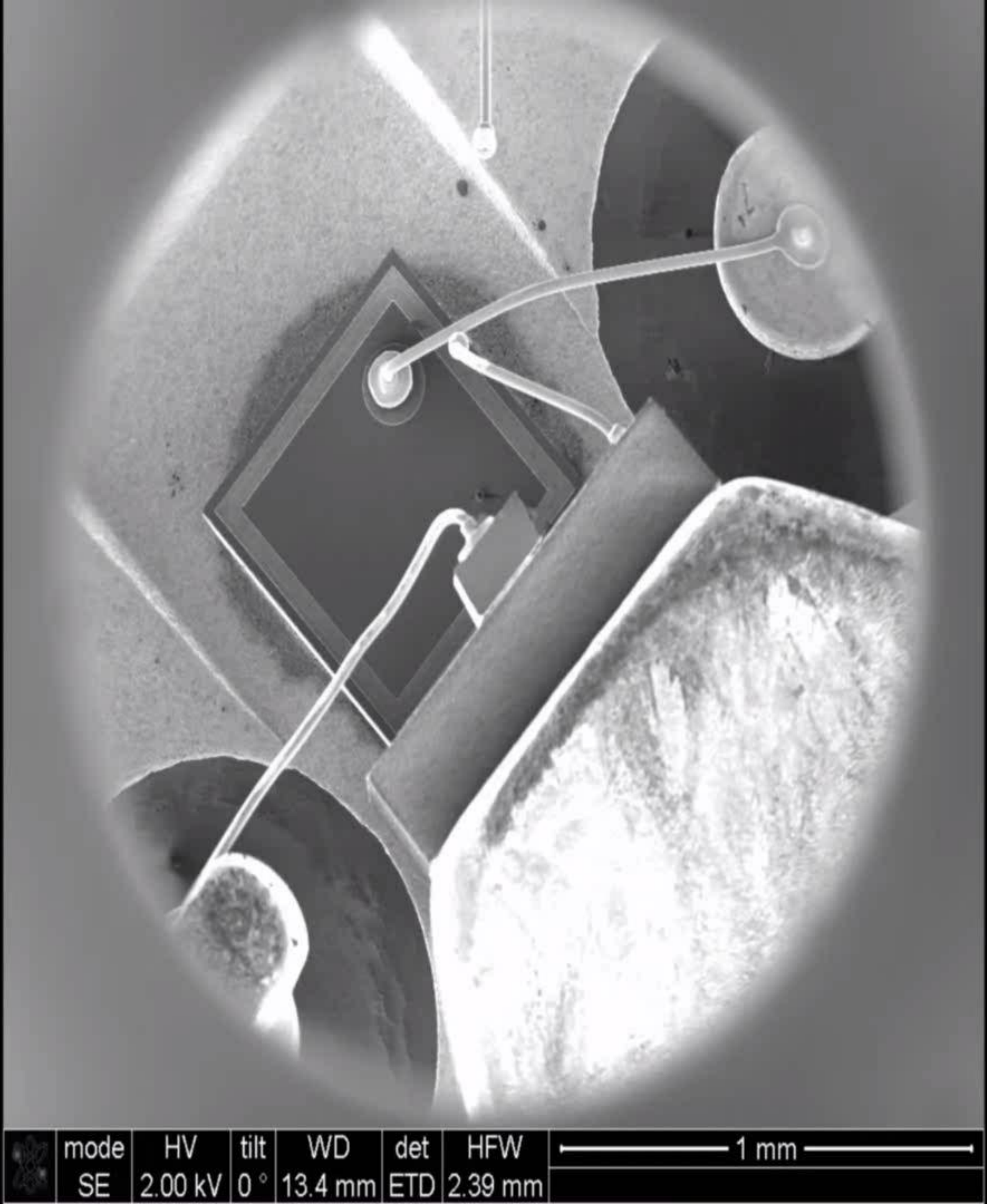

mode
SE
HV
2.00 kV
tilt
48 °
WD
4.9 mm
det
ETD
HFW
1.71 mm
500 µm


47.99 µm (s)
mode SE
HV 2.00 kV
tilt 48 °
WD 4.4 mm
det ETD
HFW 731 µm
300 µm


mode
CN
HV
2.00 kV
tilt
52 °
WD
4.3 mm
det
TLD
HFW
25.6 µm
10 µm


mode
SE
HV
2.00 kV
tilt
0 °
WD
4.3 mm
det
ETD
HFW
2.01 mm
500 µm


298.5 nm (s)
mode CN
HV 2.00 kV
tilt 52 °
WD 3.8 mm
det TLD
HFW 1.28 µm
500 nm


mode
SE
HV
2.00 kV
tilt
0 °
WD
13.4 mm
det
ETD
HFW
2.39 mm
1 mm