

Efficient electron cloud mitigation with novel low SEY Laser-Engineered Surface Structures (LESS)

Reza Valizadeh ¹, Oleg Malyshev ¹,

Svetlana Zolotovskaya ^{1 & 2},

Allan Gillespie ² & **Amin Abdolvand ²**

a.abdolvand@dundee.ac.uk

1. STFC TEAM: ASTeC, STFC Daresbury Laboratory, UK.

2. DUNDEE TEAM: University of Dundee, UK.

Part I
DUNDEE TEAM

**Laser-Engineered Surface Structures
(LESS)**

DUNDEE TEAM



Materials & Photonics Systems (MAPS) Group

www.mapsatpm.org.uk

- ① Fabrication & processing of novel functional materials;
- ② Laser functionalisation of traditional materials;
- ③ Complex photonics.

IMPACT & POTENTIAL APPLICATIONS:

storage of information, sensing, circuitry & security, energy sector, particle accelerators, healthcare & creative industries fundamental optical studies, beam shaping, laser technology.



What is “manufacture with light”?

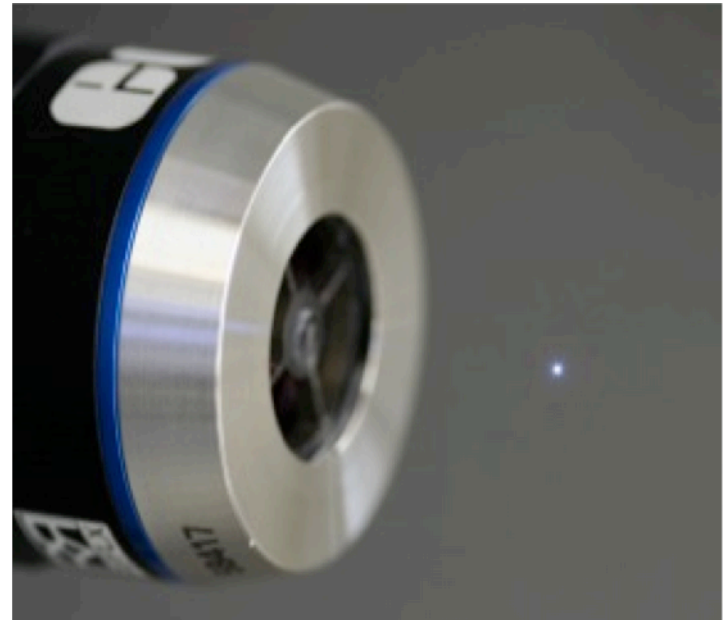
Case in point

Wavelength: 400 nm

Pulse length: *fs* or *ps*

Focal spot diameter: $\sim 1 \mu\text{m}$

Intensity: $\sim \text{TW}/\text{cm}^2$



Manufacture with light

Case in point

Material: Anodised aluminium

Processing speed: 1200 mm/s

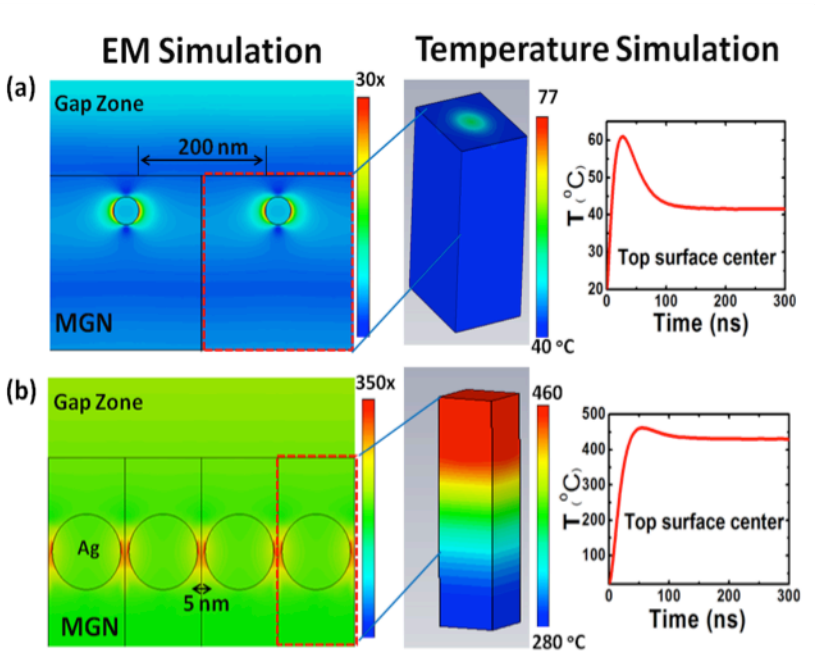
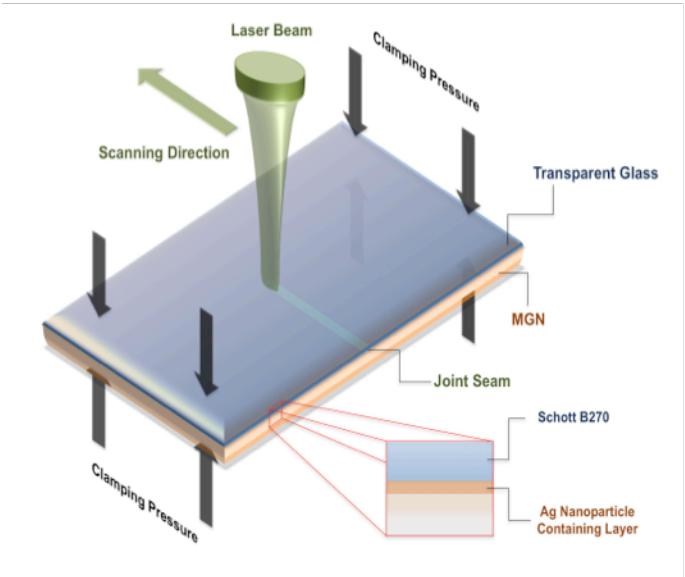
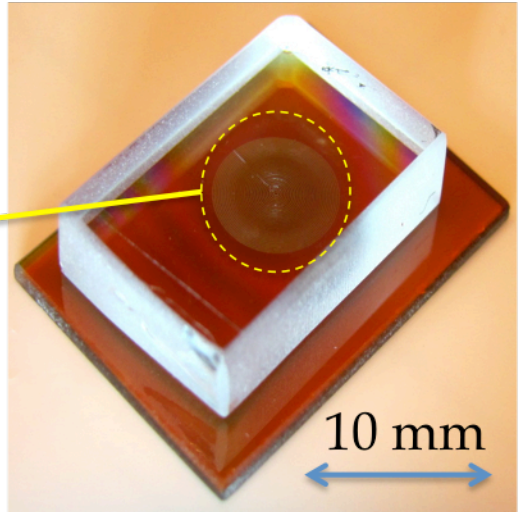
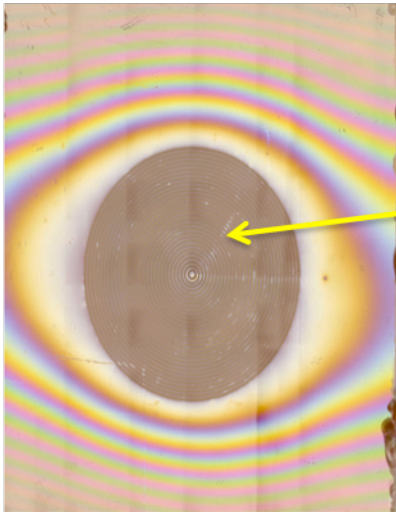
Movie 1

www.mapsatepm.org.uk

Manufacture with light

Rapid laser joining of glass

Case in point
Wavelength: 532 nm
Pulse length: ~ 40 ns at 100 kHz
Laser fluence: ~ 0.2 J/cm²
Focal spot diameter: 60 μm
Processing speed: 10 mm/s
Weld strength: ~ 13 MPa



Applied Physics Letters 105, 083109 (2014).
 Patent.

Manufacture of plasmonic substrates

Case in point

Wavelength: 355 nm

Processing speed: 20 mm/s

Movie 2

www.mapsatepm.org.uk



- Appl. Phys. A (Rapid Commun.) 109, 45 (2012).
- Optics Express 22, 5076 (2014). + Patent

LESS: making special surfaces

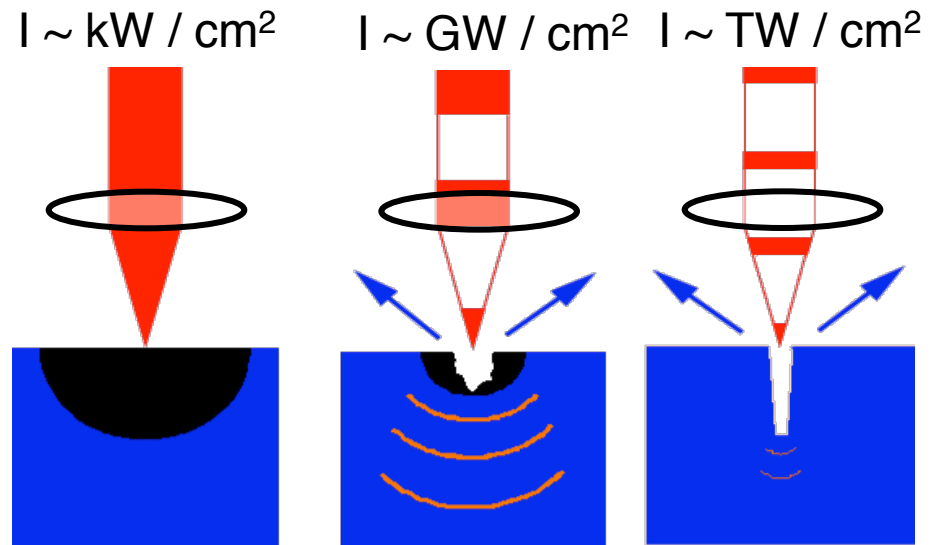
Movie 3

www.mapsatepm.org.uk

What are the components of light control?

Laser-Engineered Surface Structures (LESS)

- Wavelength
- Energy & Power
- Spot size & shape of the beam
- Pulse length



Part of this **ENERGY** (once randomised) is

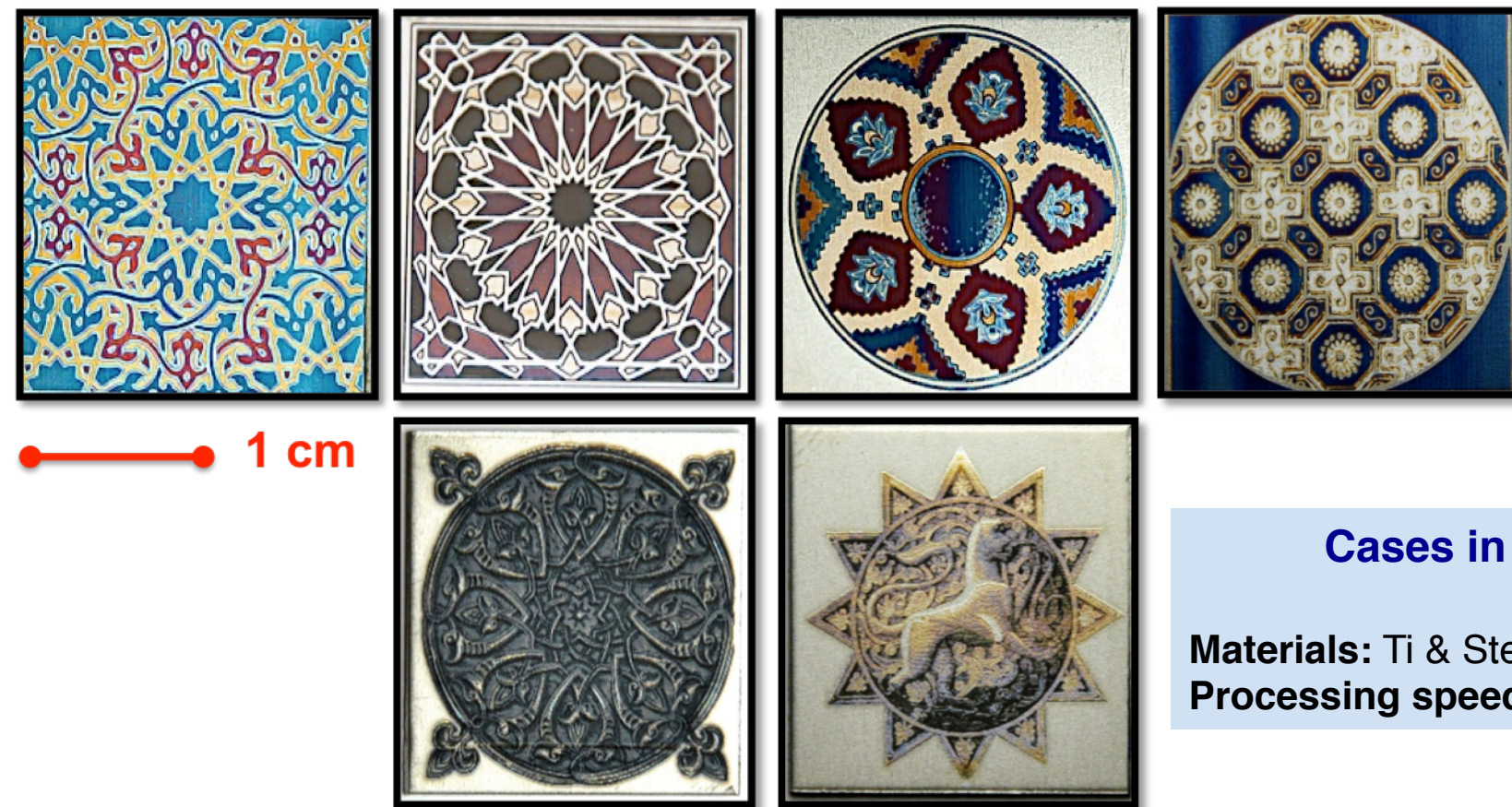
- Conducted into the bulk of the material, while*
- Part is converted into directed kinetic energy by thermal expansion of the heated layer.*

Phenomena at high irradiances: **TWO** distinguishable regimes are identified:

- Short (**ns**) pulses: Dominated by the expansion and ablation of material;*
- Ultra-short (**ps** & **fs**) pulses: Dominated by heat conduction, as hydrodynamic motion during the pulse duration is negligible.*

How much control do we have?

Laser Refractive Index Engineering of Metals



Cases in point

Materials: Ti & Steel
Processing speed: 100 mm/s

**Organised
or simply
self-organised structures?**

Laser-Engineered Surface Structures (LESS)

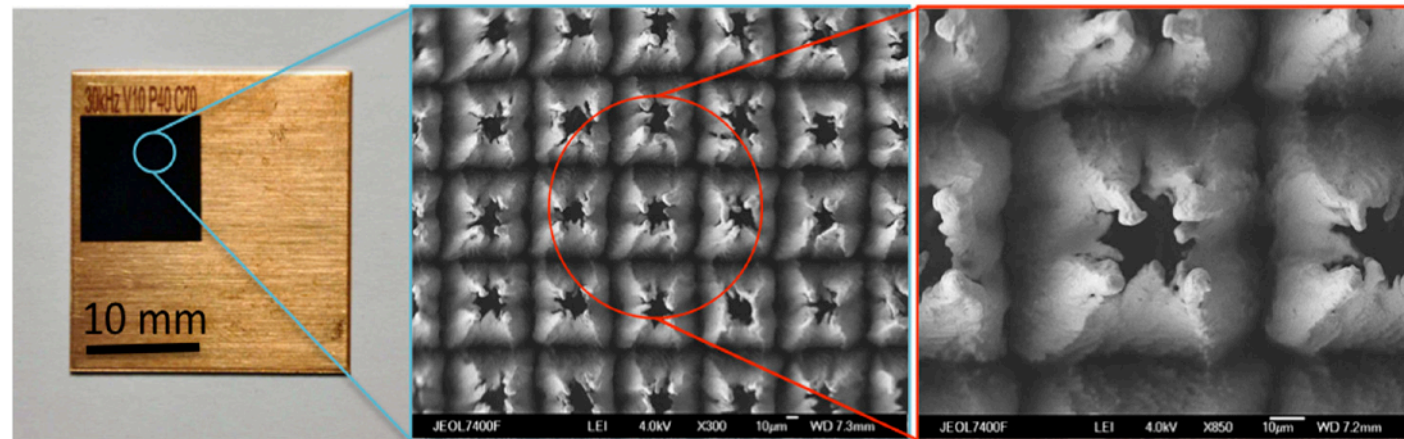
Case in point

Material: Copper

Processing speed: 10 mm/s

Movie 4

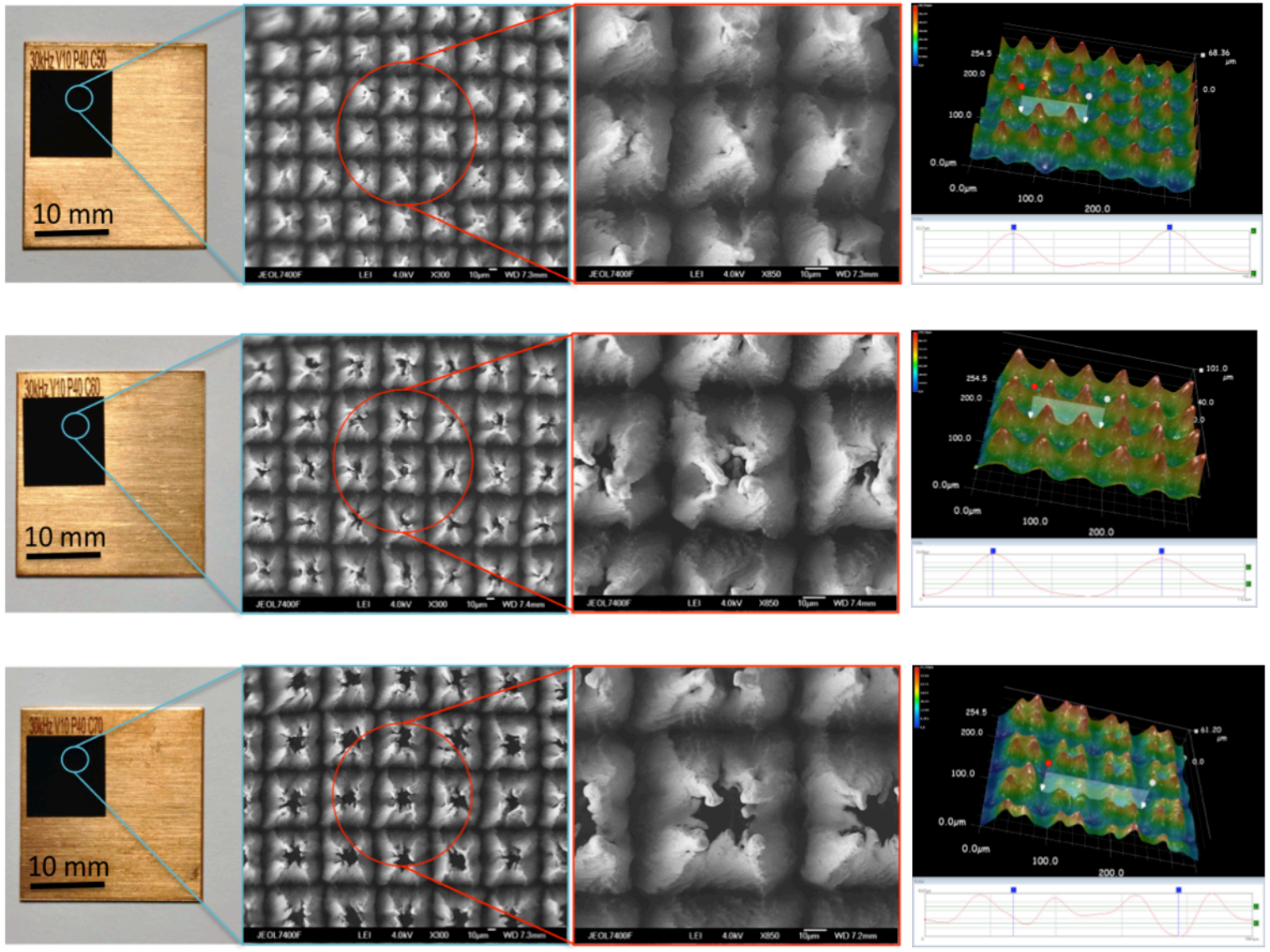
www.mapsatepm.org.uk



Appl. Phys. Lett. 101, 2319021 (2012). **Physics Highlights – Physics Today** (February 2013).
Opt. Mater. Exp. 1, 1425 (2011).

Laser-Engineered Surface Structures (LESS)

Case in point
Material: Copper



Appl. Phys. Lett. 101, 2319021 (2012). Physics Highlights – Physics Today (February 2013).
Opt. Mater. Exp. 1,1425 (2011).

**What do we need to know about
the metal?**

Case in Point: Copper (Cu) – Preliminary considerations

Metal

- Molar mass (M_r) ~ **63.5 g mole⁻¹**
- Mass density at 300 K (ρ) ~ **8.96 g cm⁻³**
- Thermal diffusivity (D) ~ **$1.1234 \times 10^{-4} \text{ m}^2 \text{ s}^{-1}$**
- Reflectivity > **90 % (IR)**
- Thermal conductivity: **401 W m⁻¹ K⁻¹**

Laser source

- Pulse length
- Beam spot diameter
- Wavelength

Interaction

- Heat diffusion length (L_T) - ?
- The heated volume (V_{Pulse}) - ?
- Mole of the heated volume (V_{mol}) - ?
- Enthalpy per pulse for the laser spot - ?

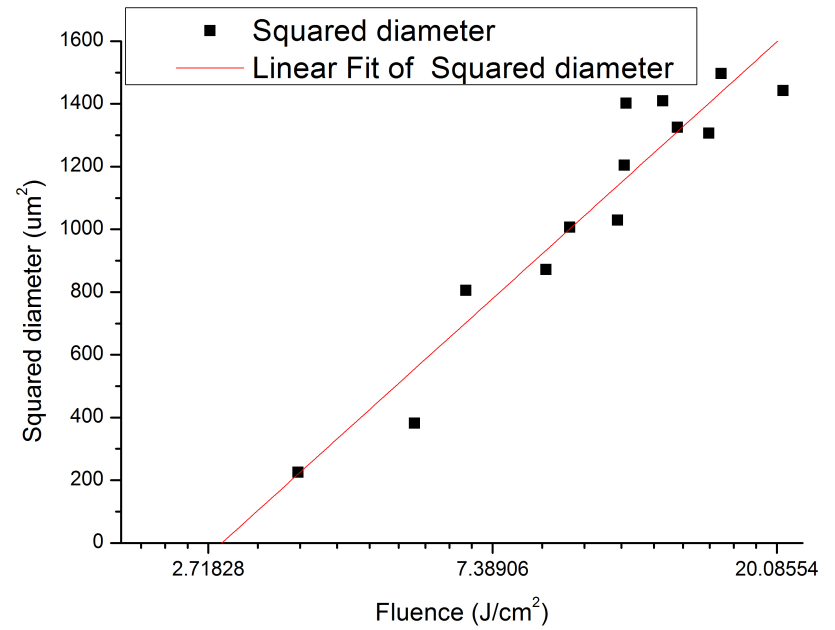
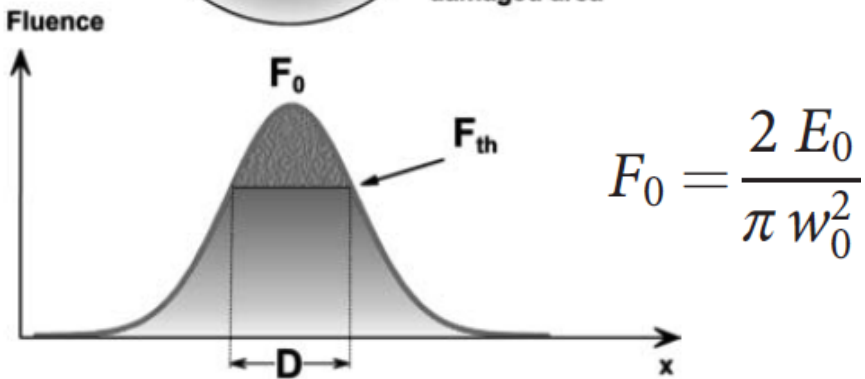
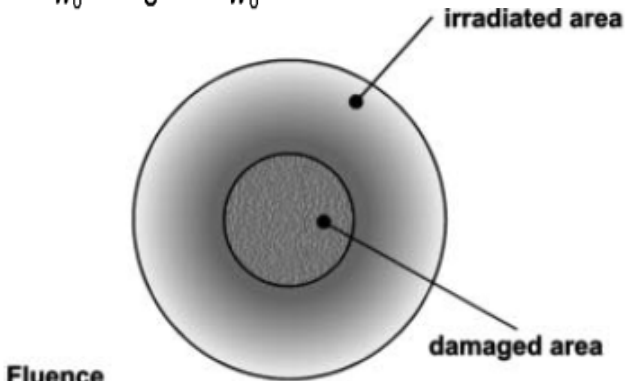
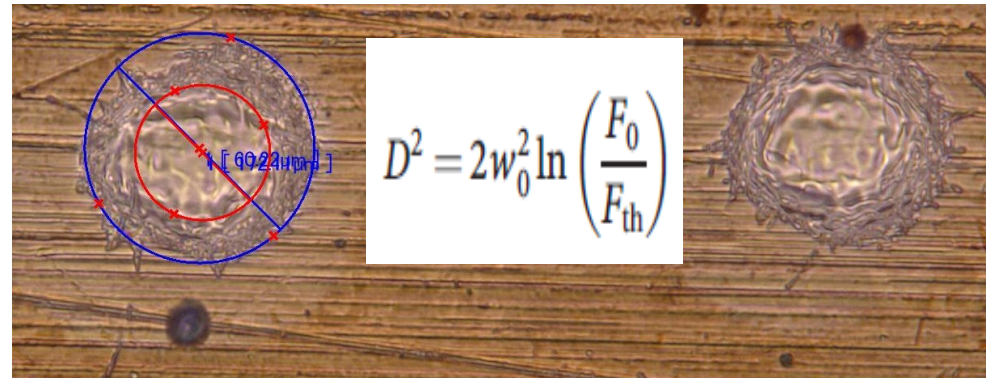
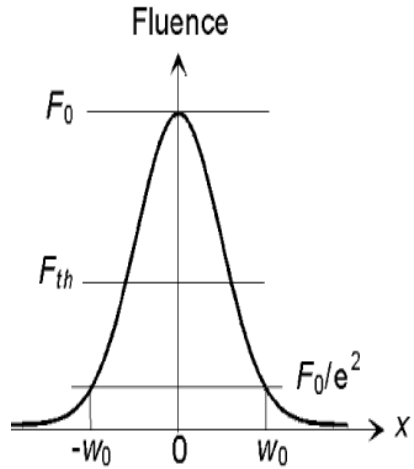


Advanced Laser Processing (ALP) Lab



Case in Point: Copper (Cu)

Practical considerations: Damage threshold



$$F_{th} \approx 1.9 \text{ J cm}^{-2}$$

What metals?

Laser-Engineered Surface Structures (LESS)

Metals

Copper

Aluminium

Titanium

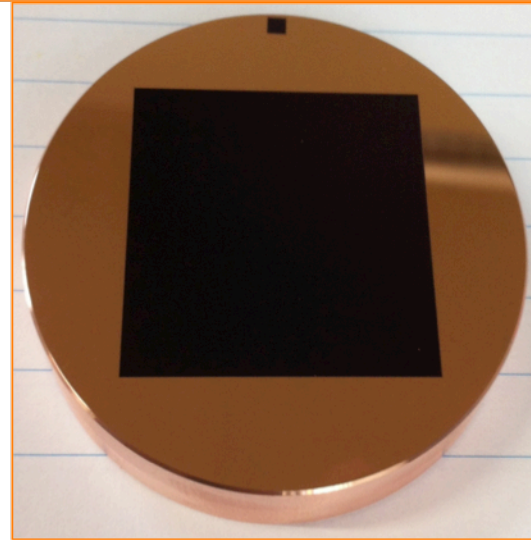
Steel

Silver

Gold

A practical example:

Laser structured **copper mirror** (optical / THz separator) - fabricated for the **Beam Diagnostics Group at Daresbury**.



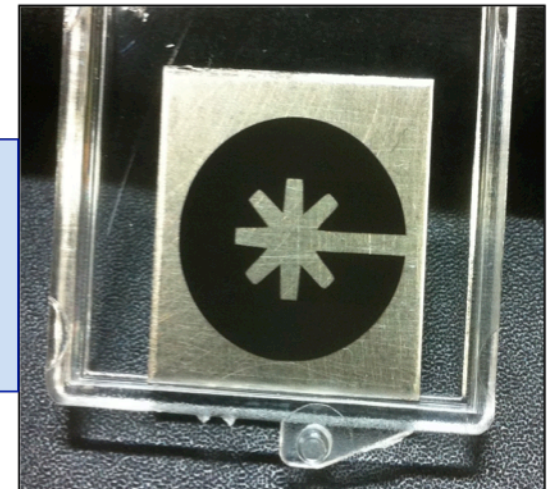
25 mm



Appl. Phys. Lett. 101, 2319021 (2012).
Opt. Mater. Exp. 1,1425 (2011).
Int. J. Adv. Manu. Technol. 66, 1769 (2013).

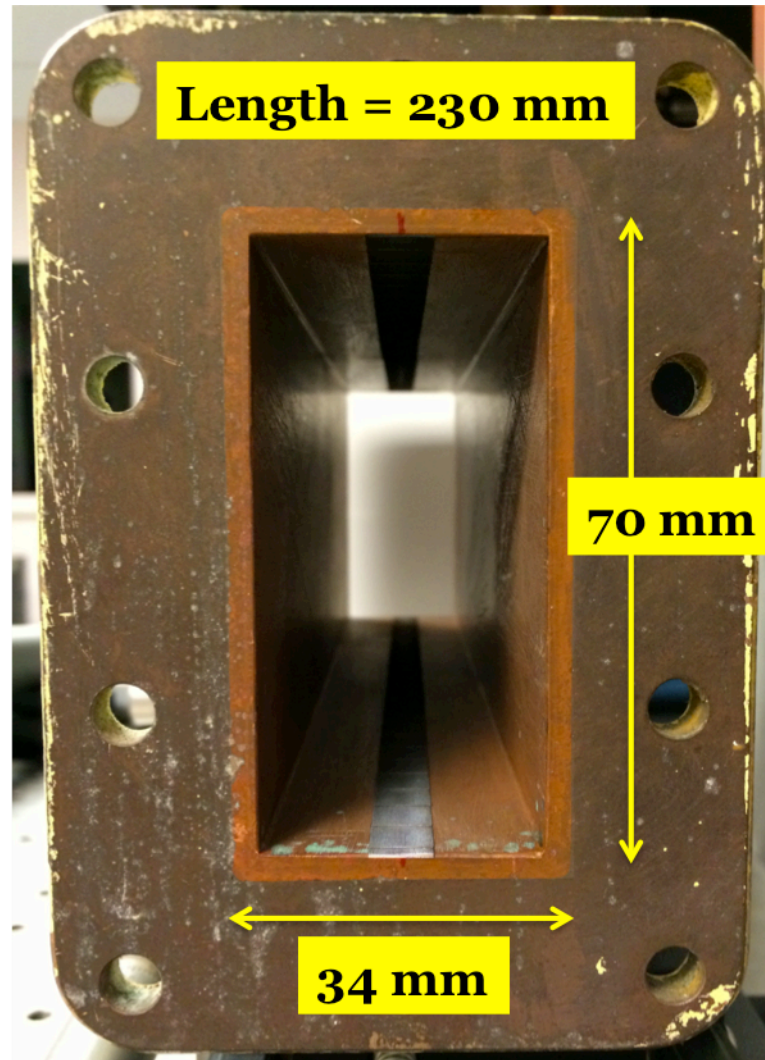
A practical example:

Laser structured **steel surface** fabricated for a major laser company.



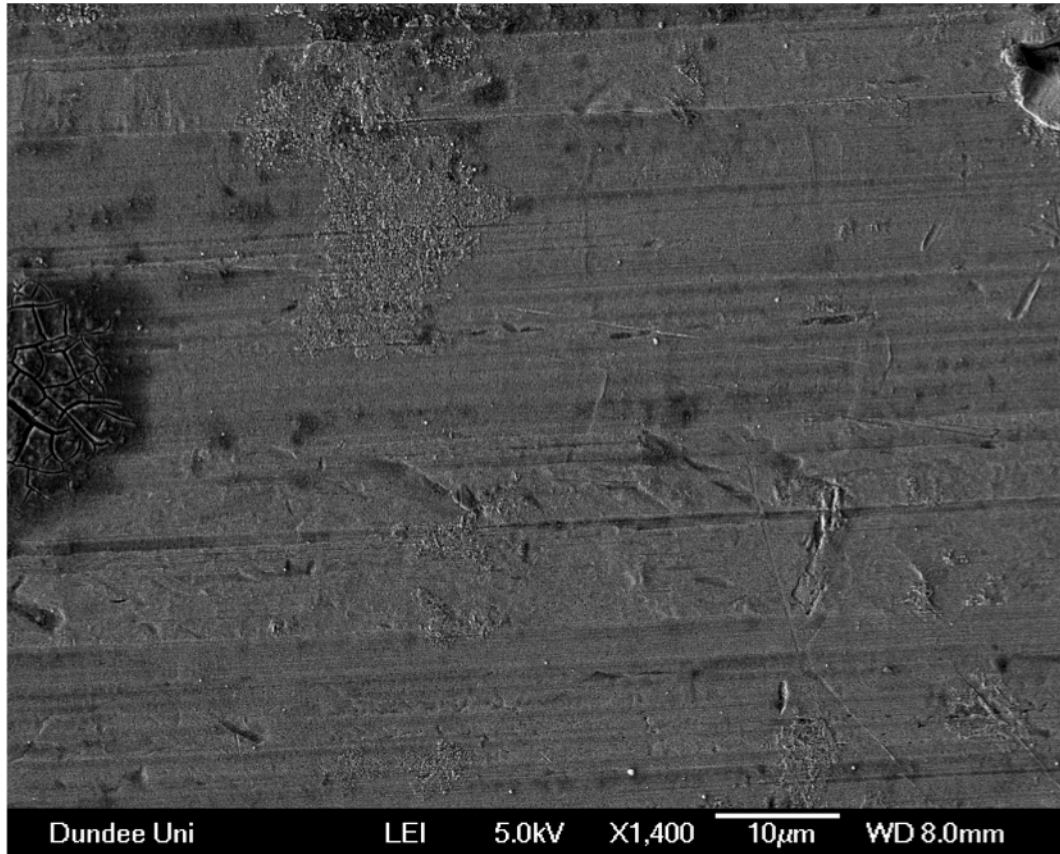
**Can we process tubes or curved
surfaces?**

Example: Copper Tube

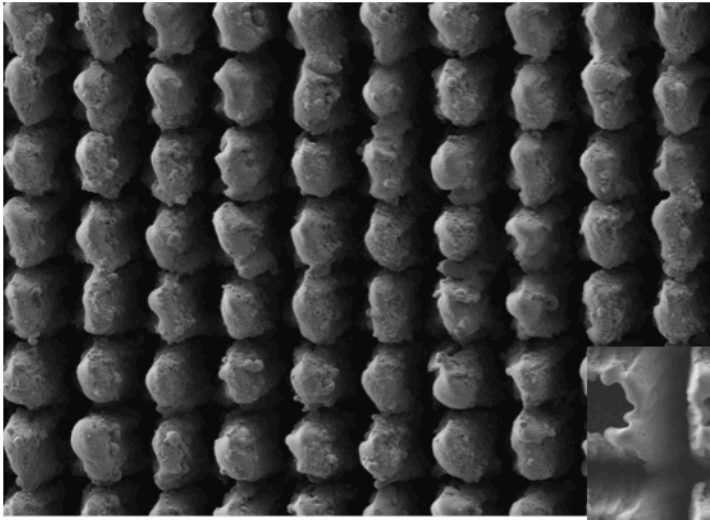


More SEM images of LESS

Example: Copper surface before laser processing

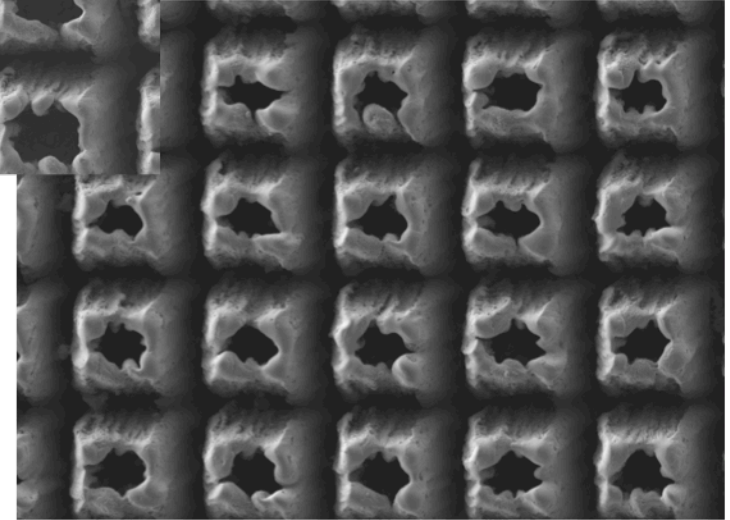
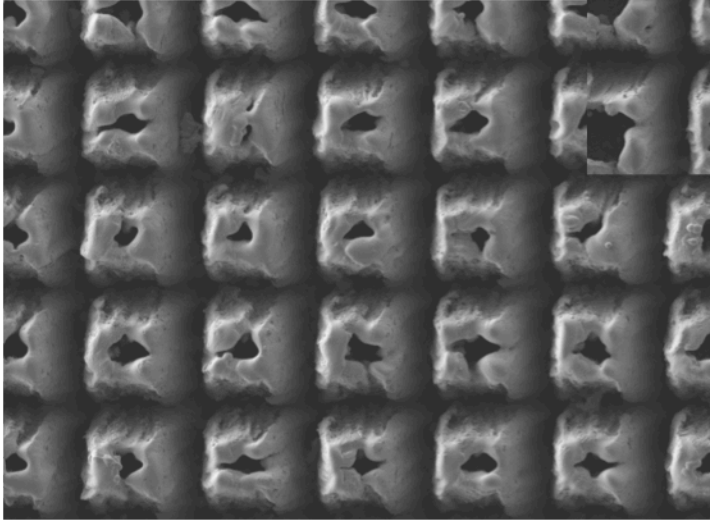
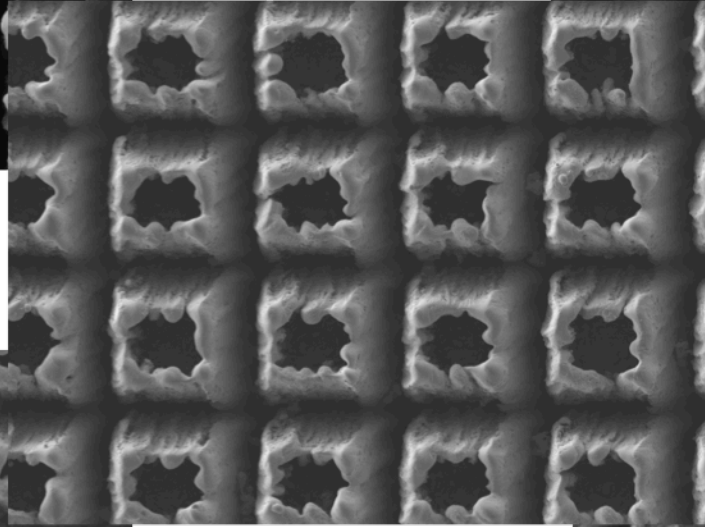
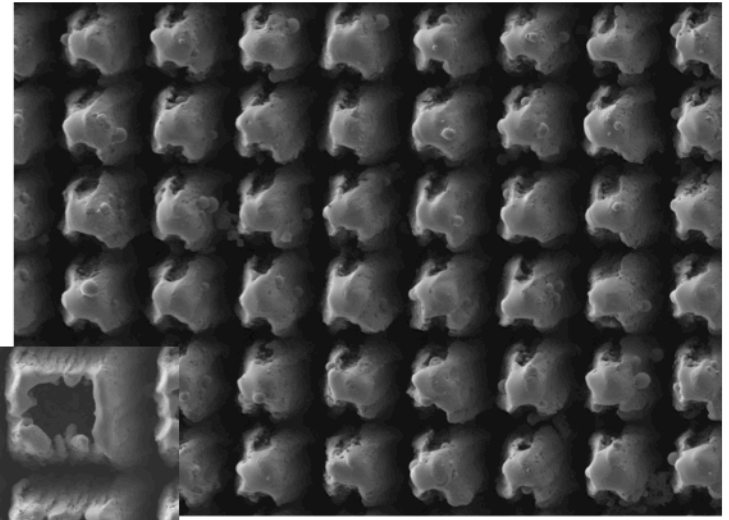


Laser-Engineered Surface Structures (LESS)



Cu: LESS

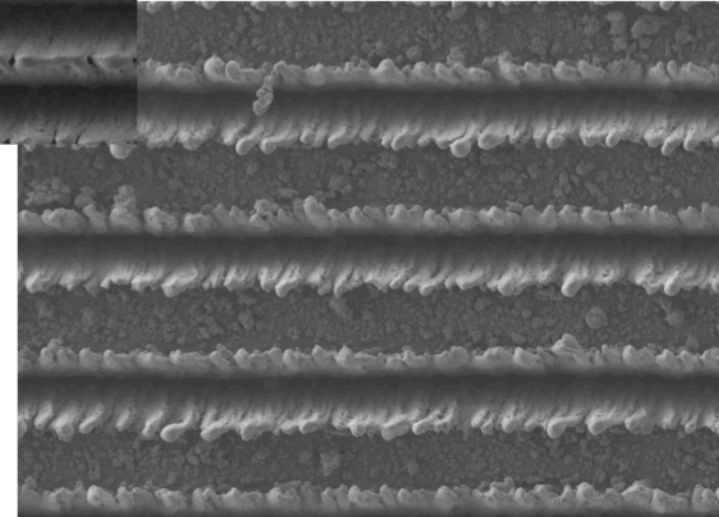
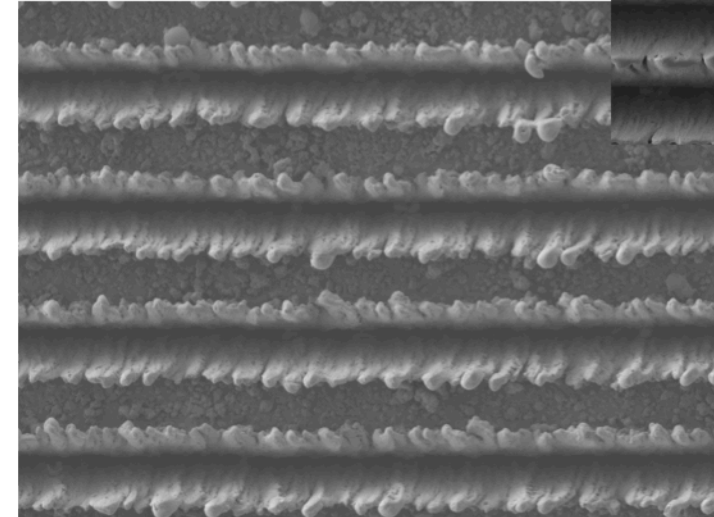
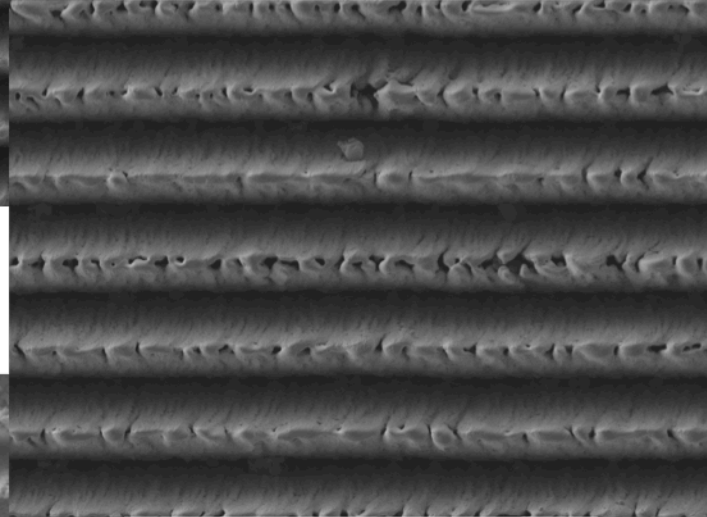
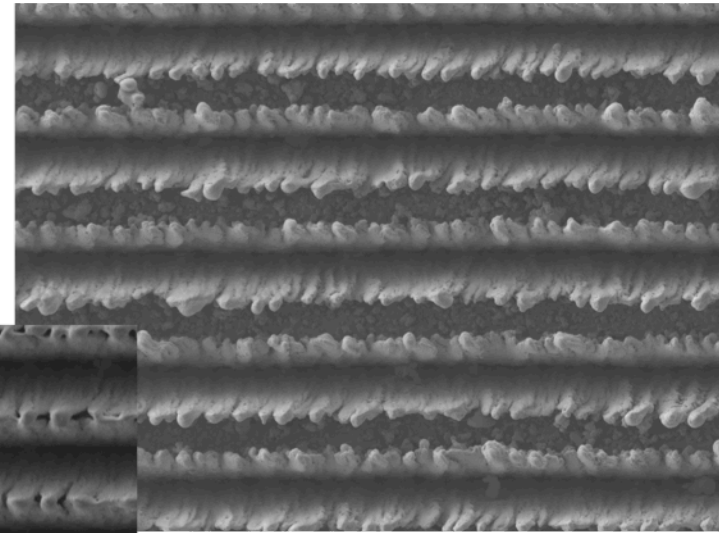
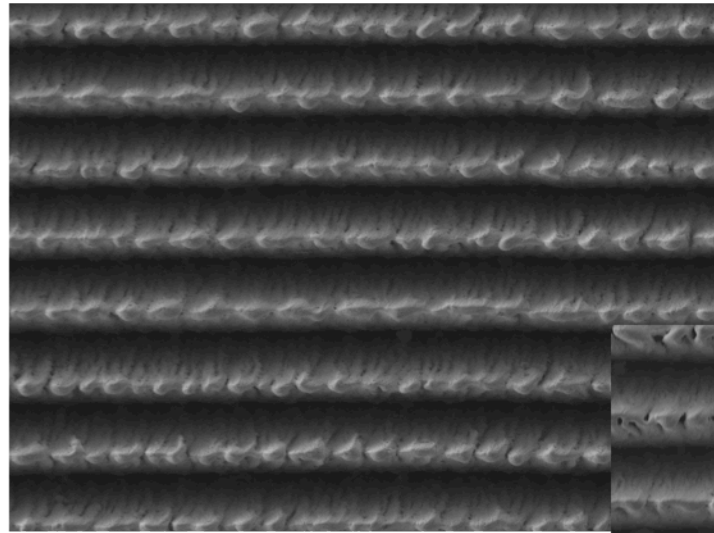
Type A



Laser-Engineered Surface Structures (LESS)

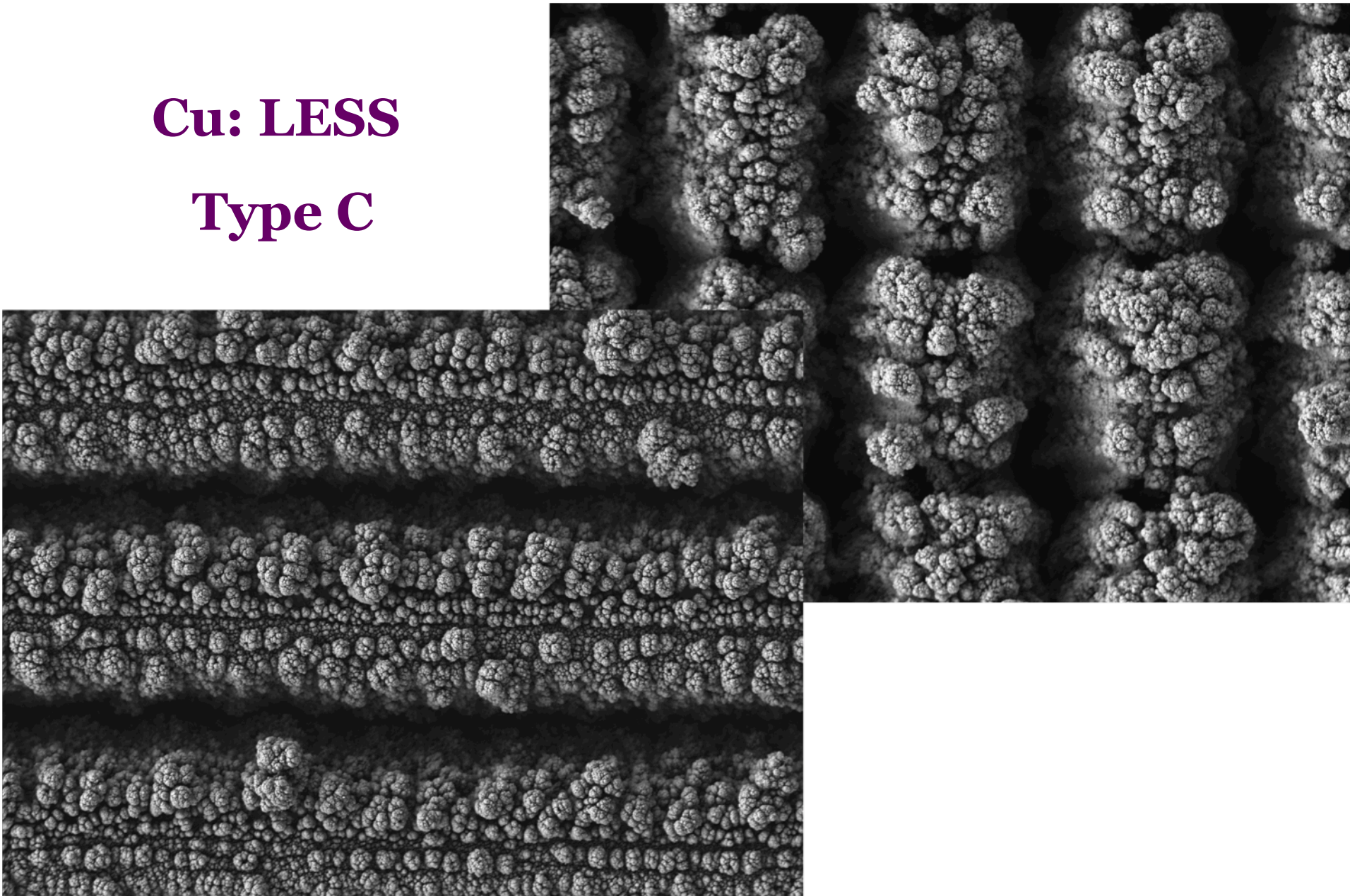
Cu: LESS

Type B



Cu: LESS

Type C



Efficient electron cloud mitigation with novel low SEY laser-engineered surface structures (LESS)

Reza Valizadeh ¹, **Oleg Malyshev** ¹,

Svetlana Zolotovskaya ^{1 & 2},

Allan Gillespie ² & Amin Abdolvand ²

1. STFC TEAM: ASTeC, STFC Daresbury Laboratory, UK.

2. DUNDEE TEAM: University of Dundee, UK.