Dielectric Material Processing Using MHz/GHz Bursts

Mantvydas Jašinskas

Chief Sales Officer / m.jasinskas@ekspla.com

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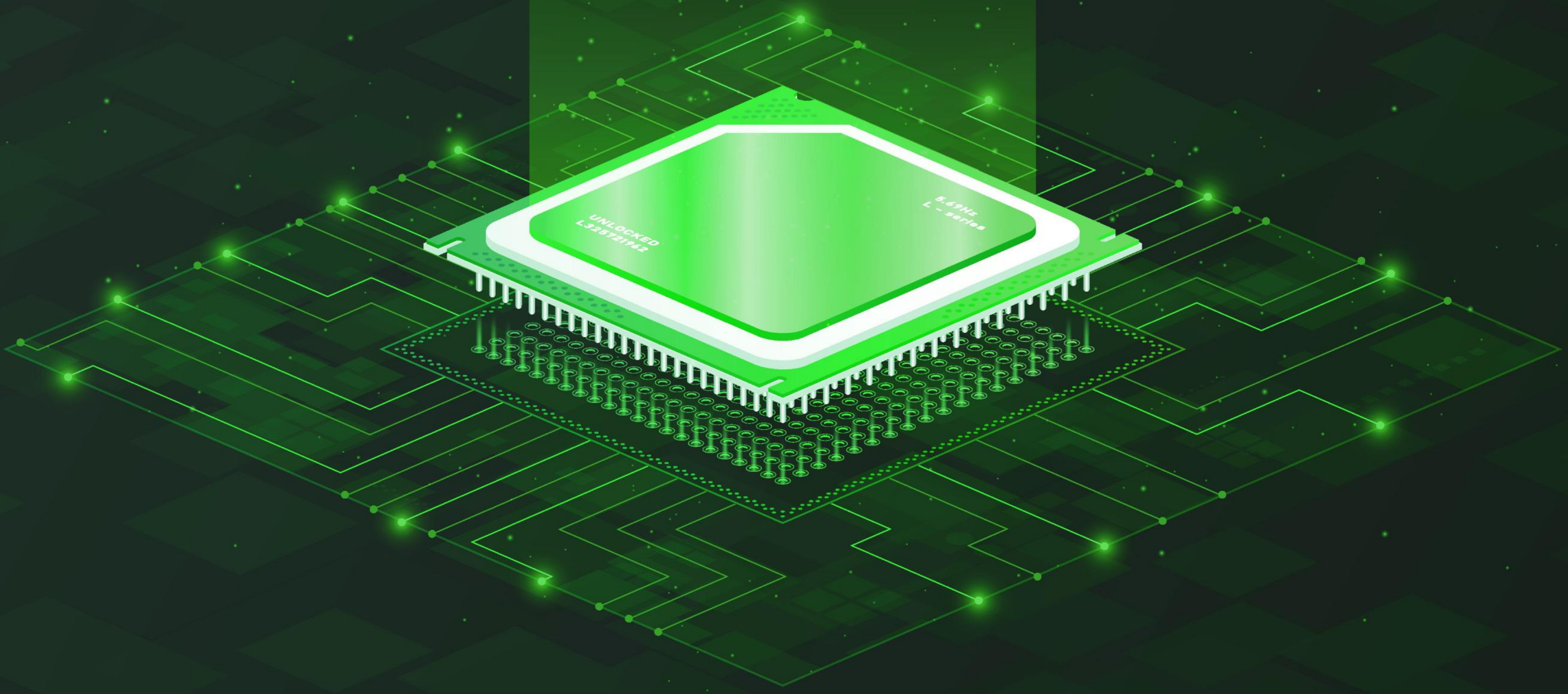
Semiconductor



Consumer

Electronic devices

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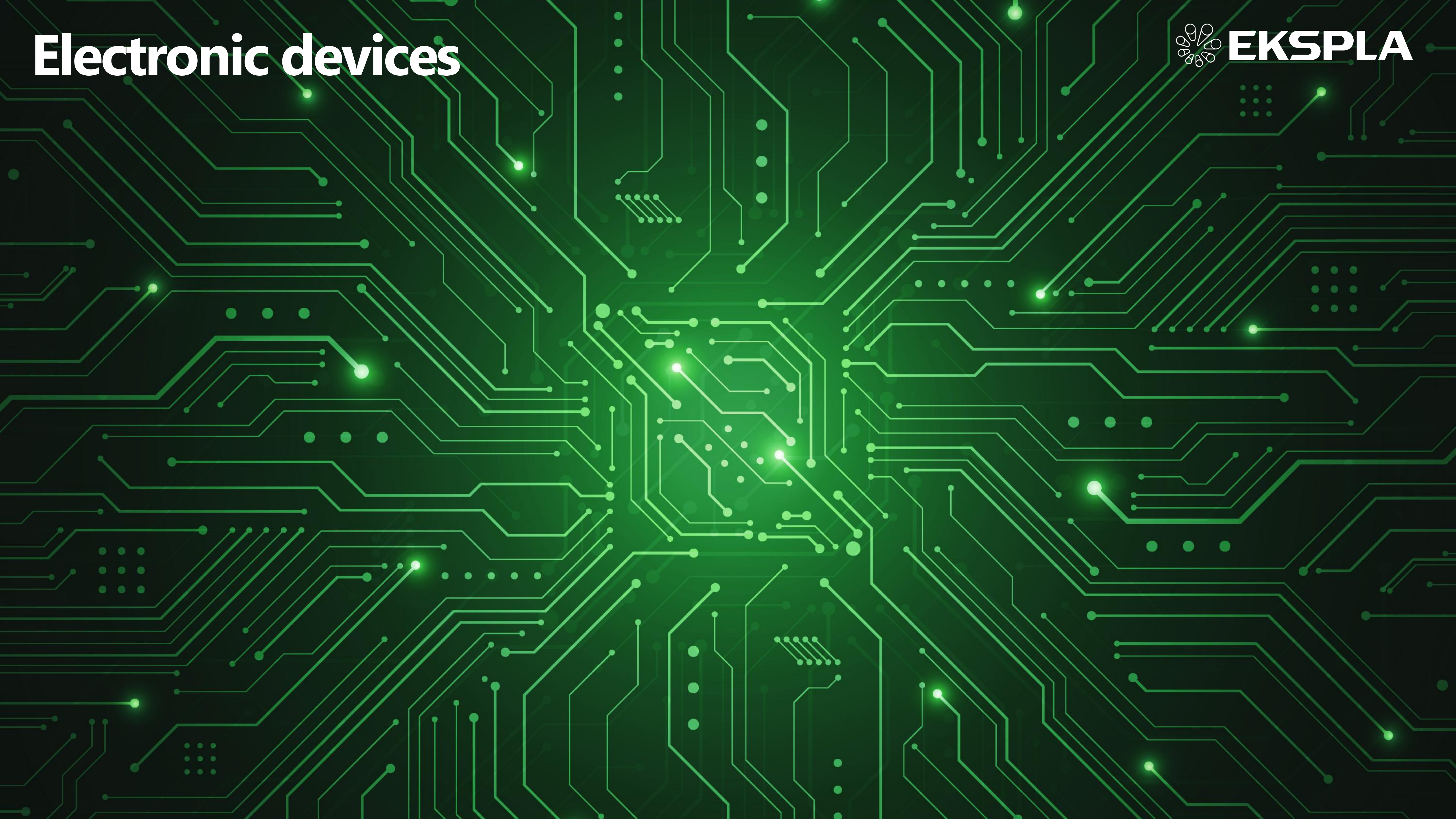

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Active Fiber Loop for GHz Burst Formation

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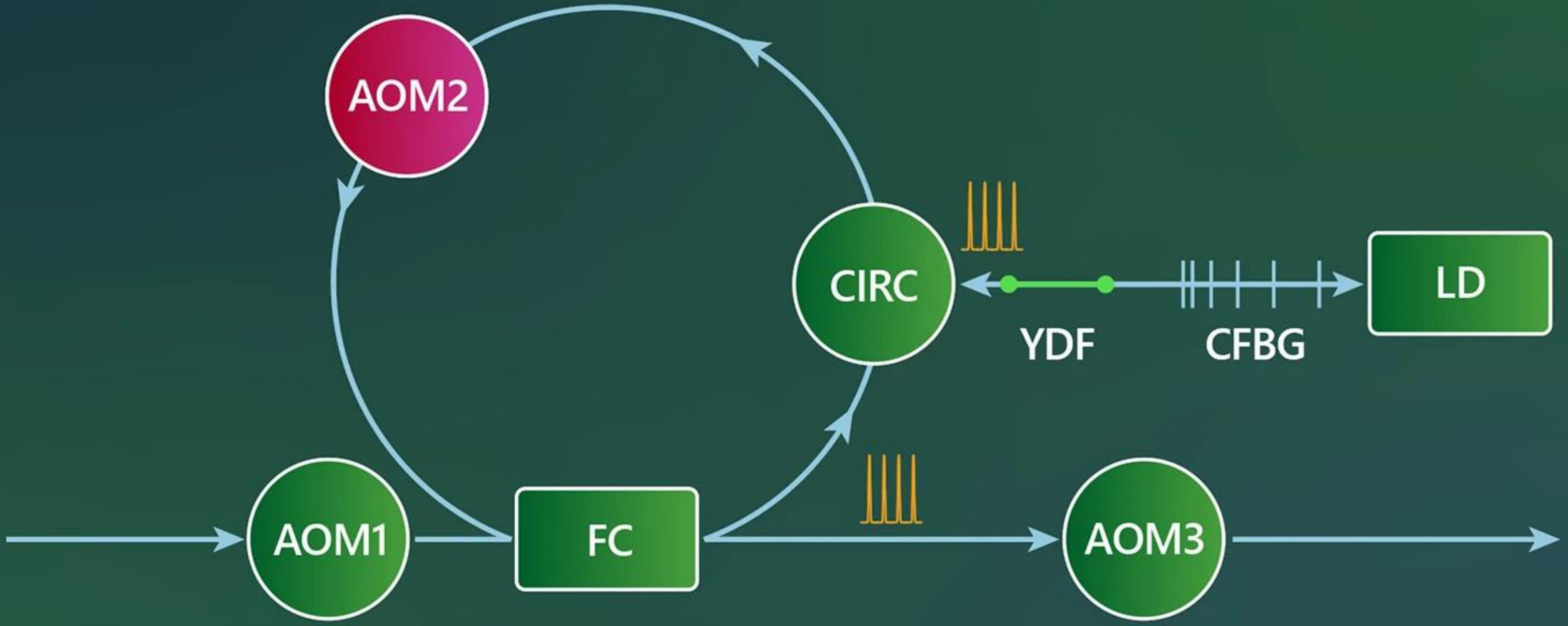

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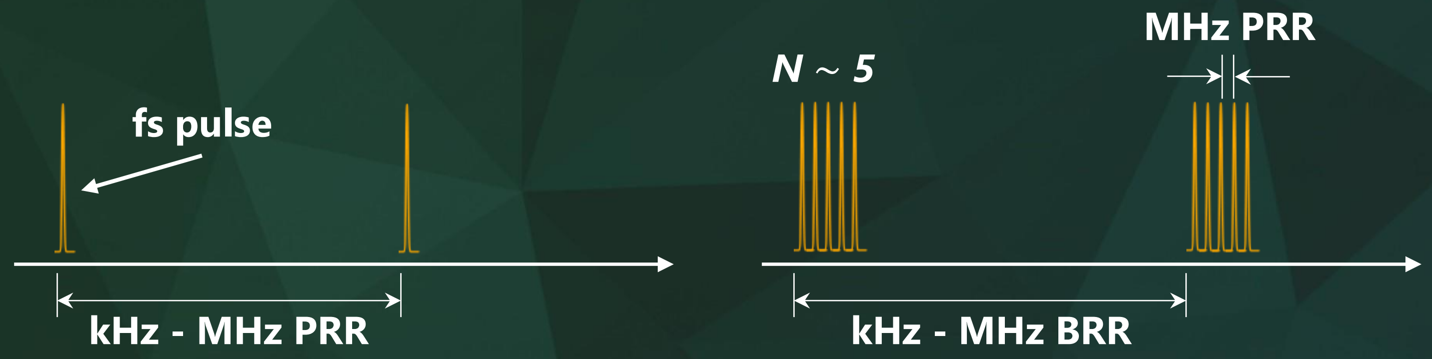
Femtosecond laser different operation modes

Single pulse mode



MHz burst mode

Femtosecond laser different operation modes

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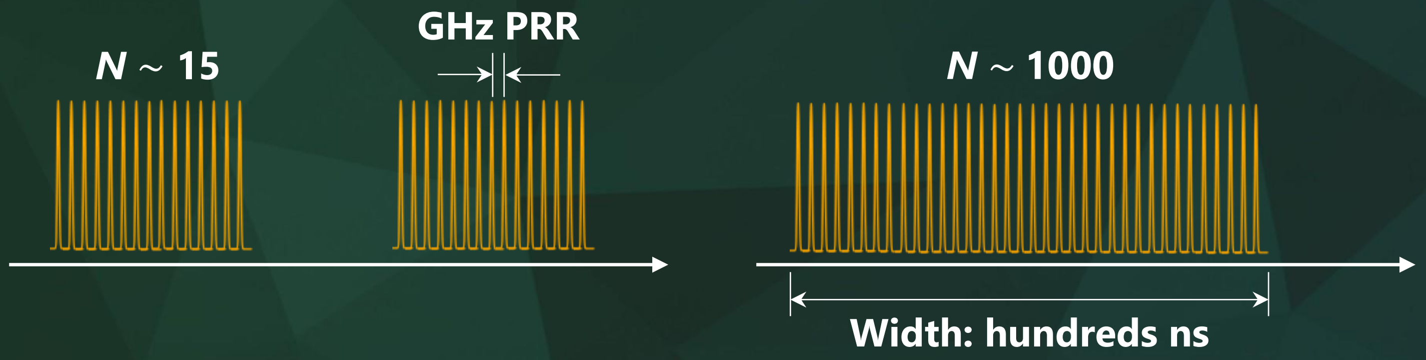
Short GHz burst mode



Long GHz burst mode

Femtosecond laser different operation modes

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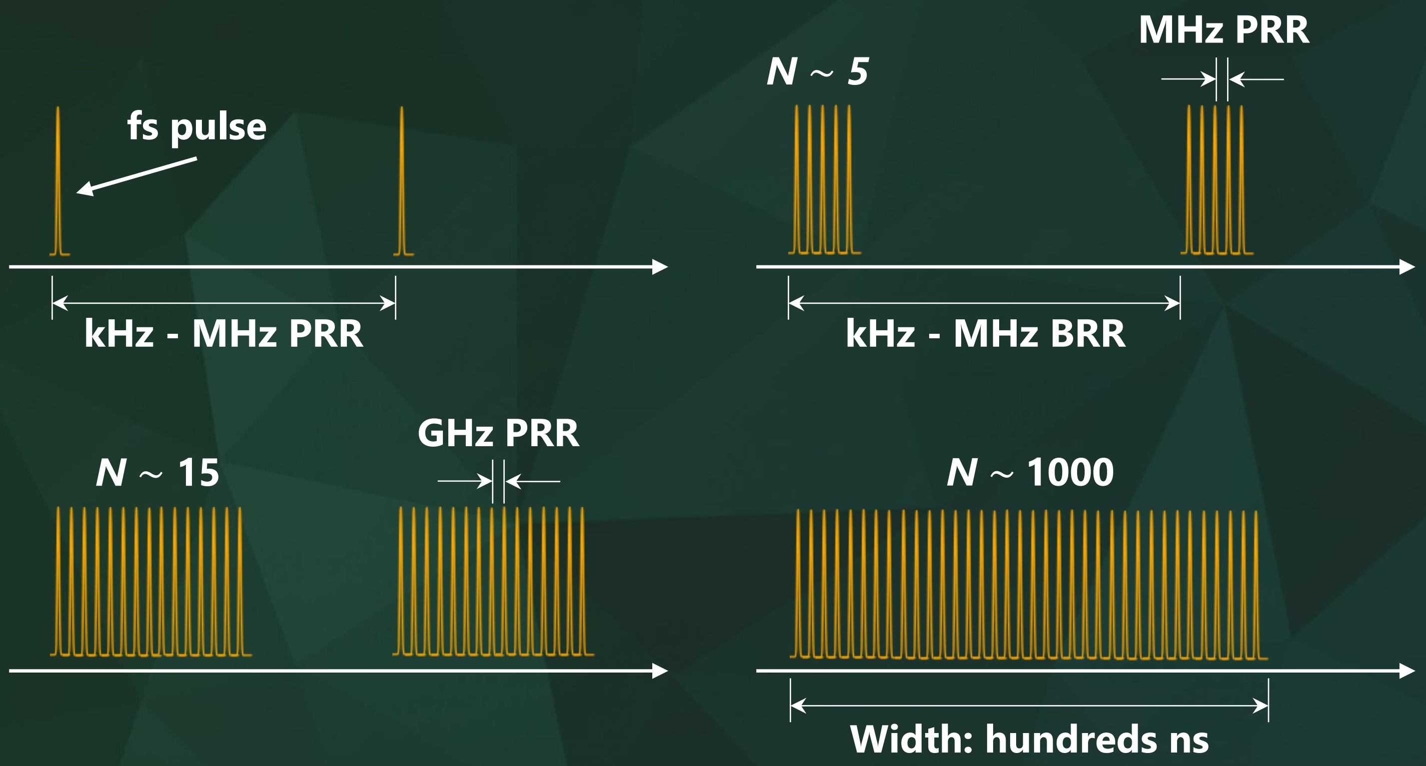
Single pulse mode

MHz burst mode



Short GHz burst mode

Long GHz burst mode

There is no single laser source which could cover all operation modes.

PRISM AWARDS WINNER

Task No 1

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Milling 1×1 mm^2 squares in alumina ceramics (Al_2O_3)

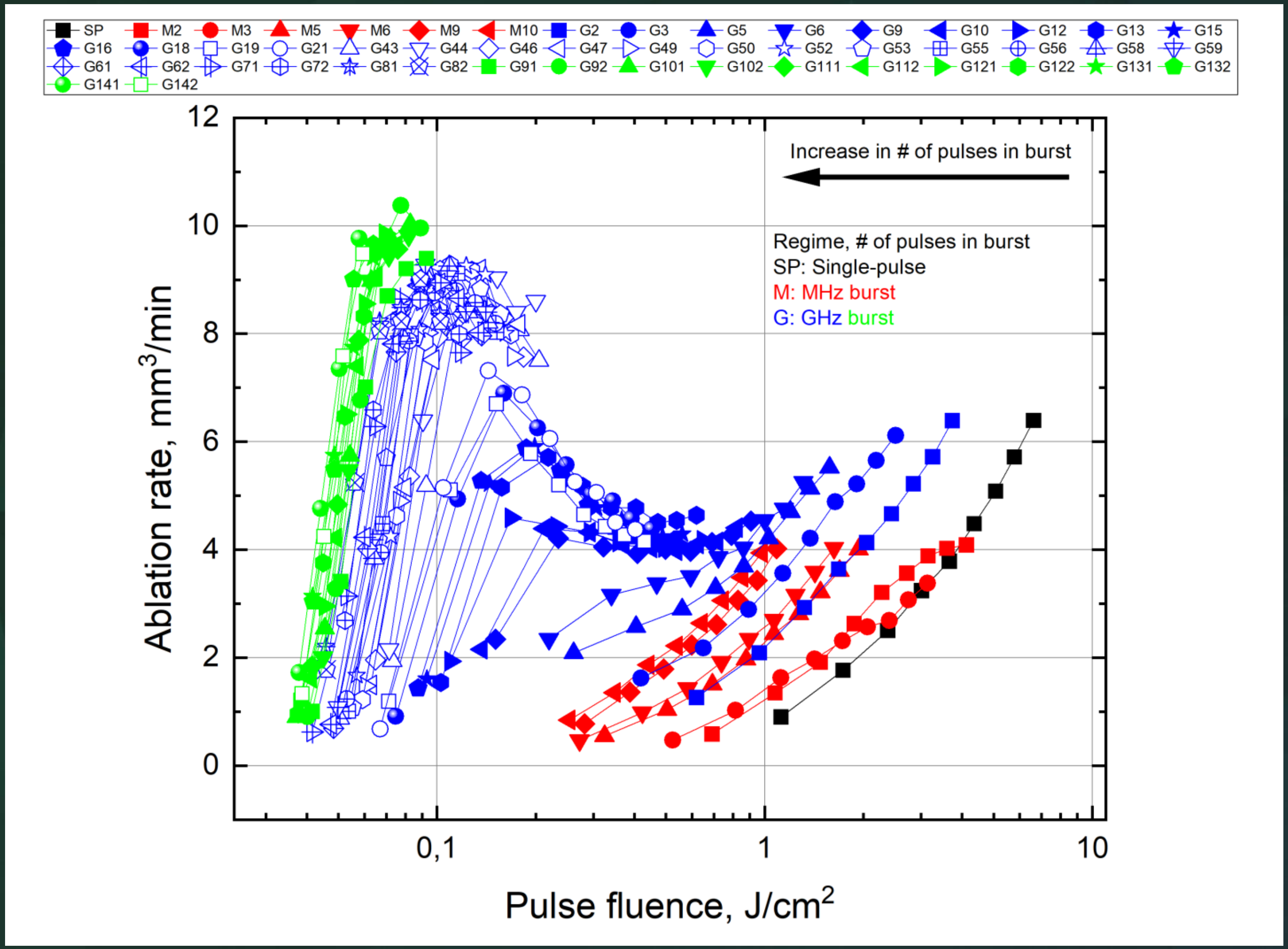
Increasing Ablation Rate with GHz Burst Mode – Al_2O_3 ceramics

/ MHz burst reduced ablation rate due to shielding of consequent pulses;

/ GHz burst allowed division of high energy pulse into multiple ones;

/ GHz burst resulted in **1.62 times** increase in throughput, compared to single-pulse.

Operation mode	**Ablation rate (mm^3/min)**
Single-pulse	6.39
MHz burst (2 p.)	4.08
GHz burst (92 p.)	**10.37**



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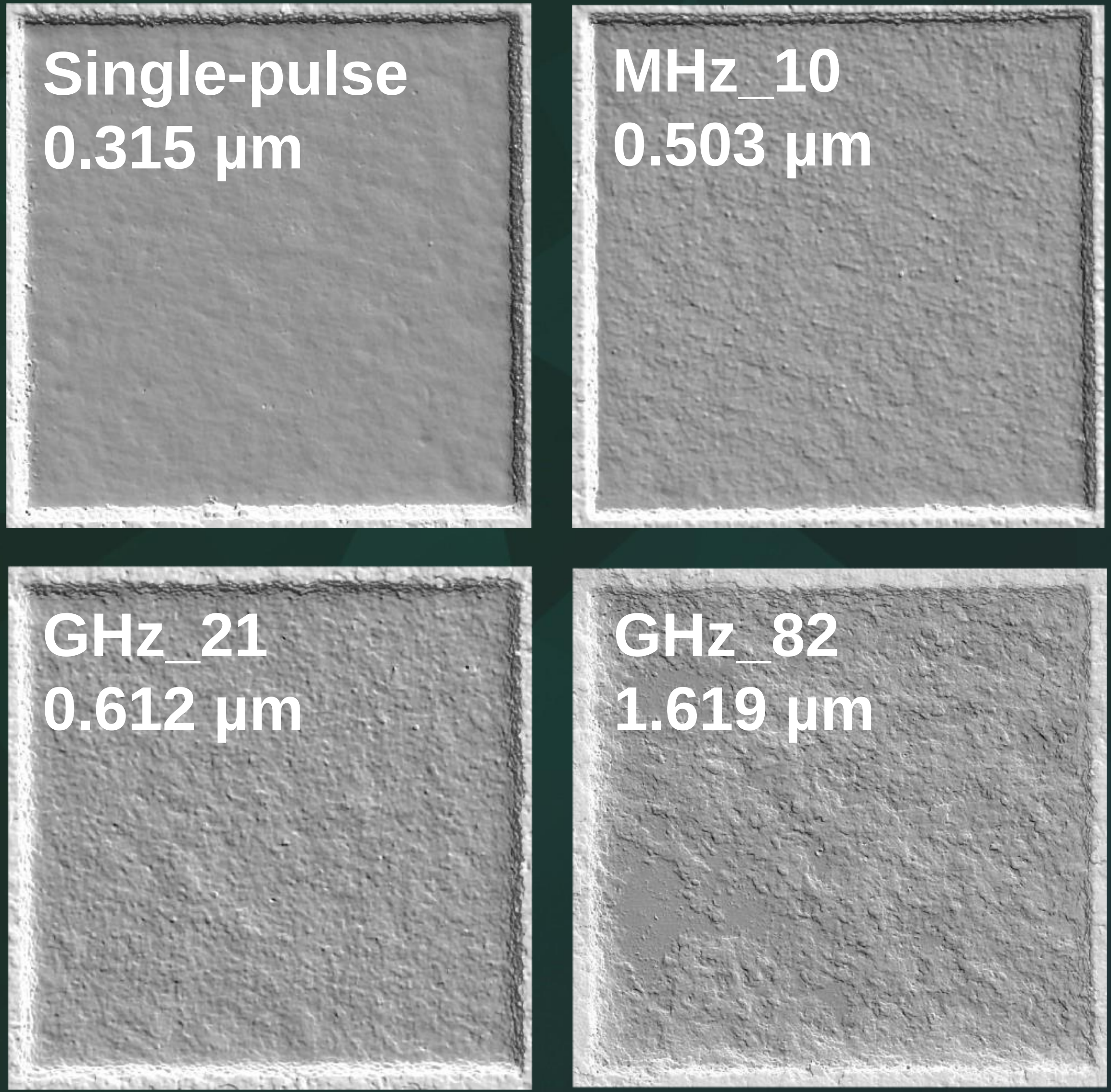
Increasing Ablation Rate with GHz Burst Mode – Al_2O_3 ceramics

/ Increasing number of pulses in burst degrades surface quality;

/ Especially for GHz burst significant thermal accumulation;

/ Post-processing step can be used in single-pulse mode to smoothen the surface.



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Task No 2

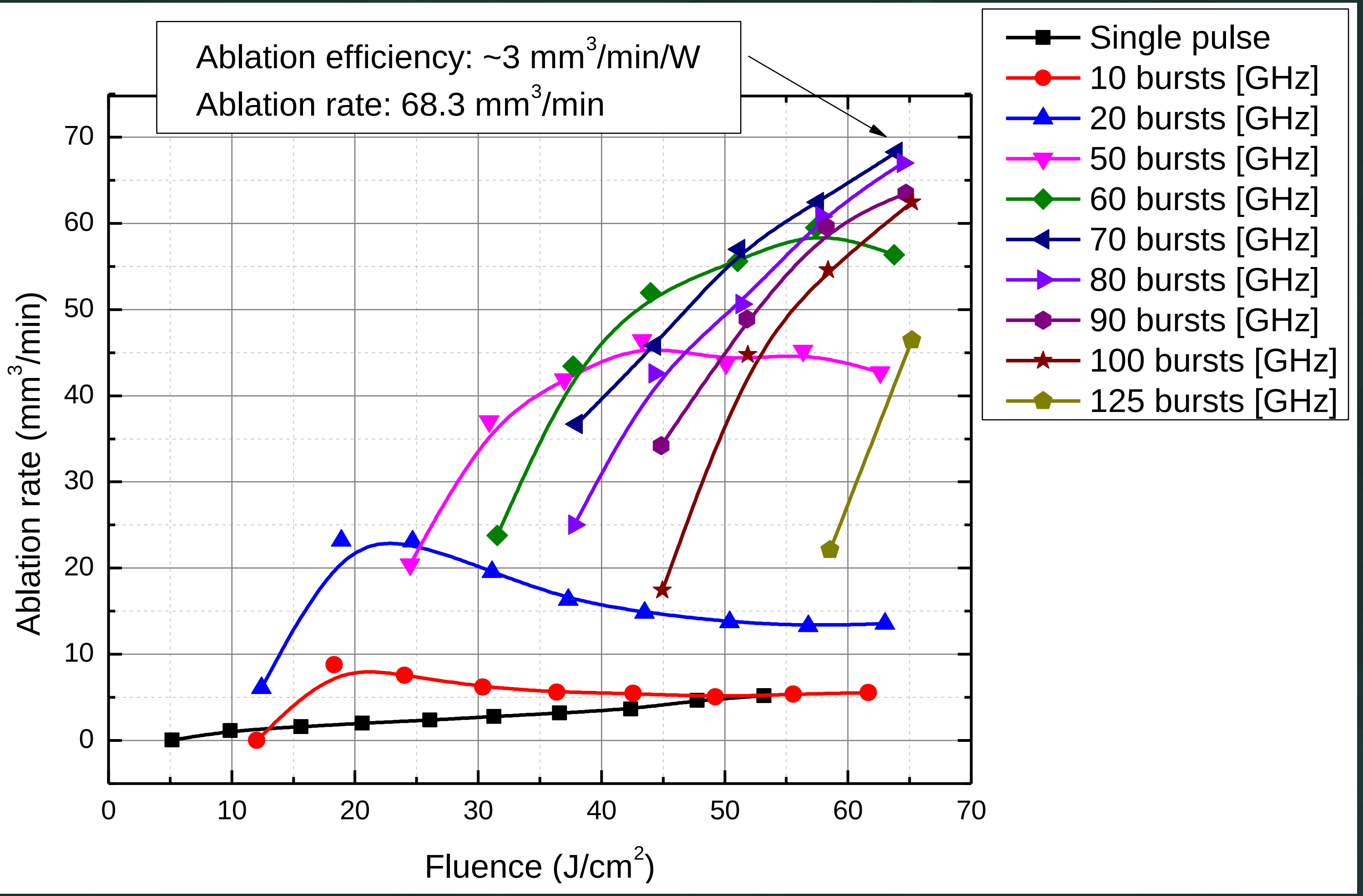
Milling 2×2 mm^2 squares in fused-silica glass

Increasing Ablation Rate with GHz Burst Mode

/ Single-pulse, GHz and MHz+GHz burst modes tested;

/ GHz burst resulted in 13.2 times increase in throughput, compared to single-pulse.

Operation mode	Ablation rate (mm^3/min)
Single-pulse	5.17
GHz burst (70 p.)	**68.3**
MHz+GHz burst	52.1



Courtesy of FTMC.

Task No 3

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Achieve >**600 mm³/min** removal rate in soda-lime glass

>**100 times** higher than TDM in single-pulse mode

Top-down Milling (TDM) Technique

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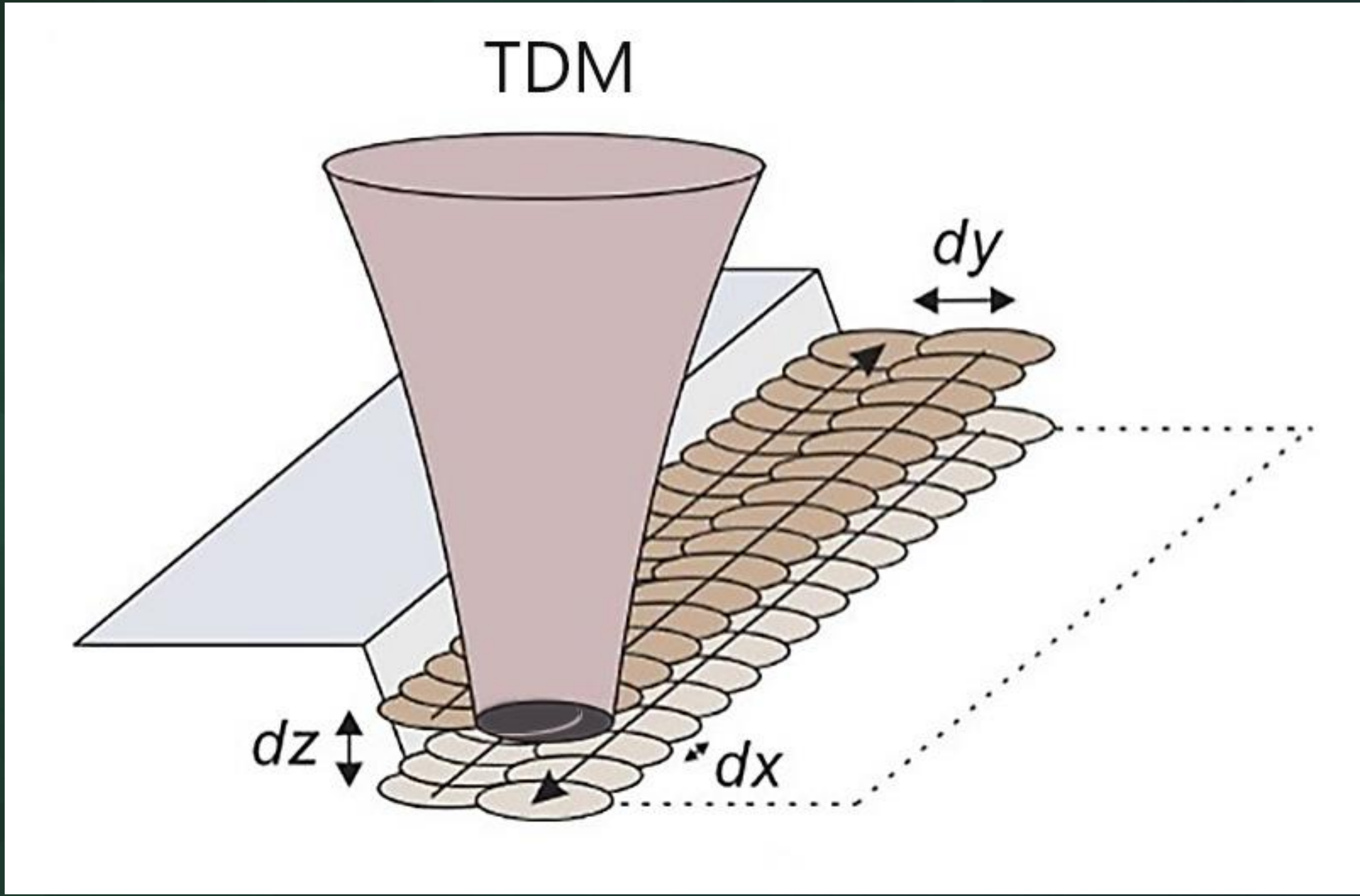
- / Top-down Milling is the most used milling technique;
- / Usually suffering from tapering, due to accumulation of ablation debris;

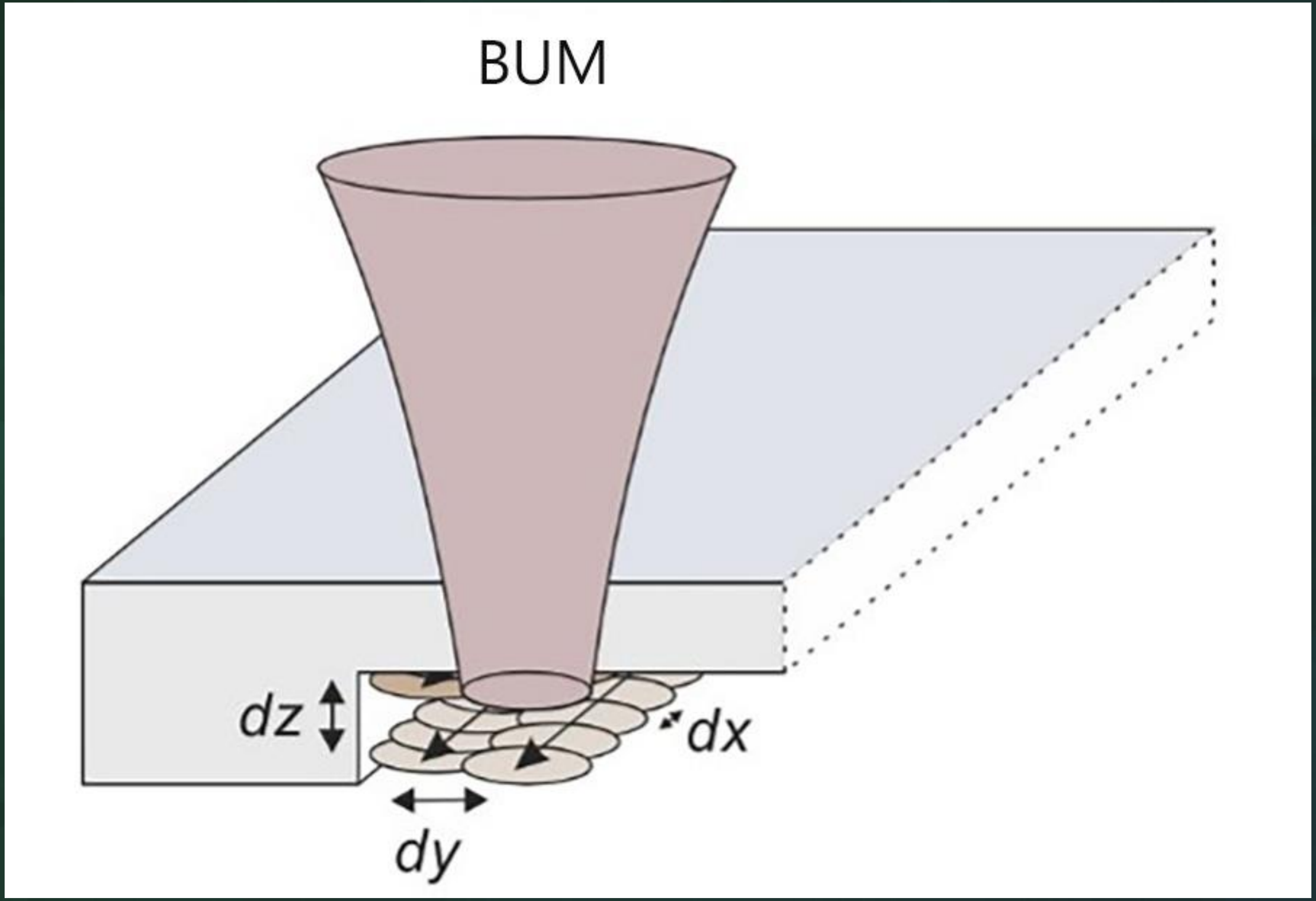


Courtesy of FTMC.

Bottom-up Milling (BUM) Technique

/ Bottom-up Milling processes the material from the bottom side – efficient removal of ablation debris with the help of pressurised air;

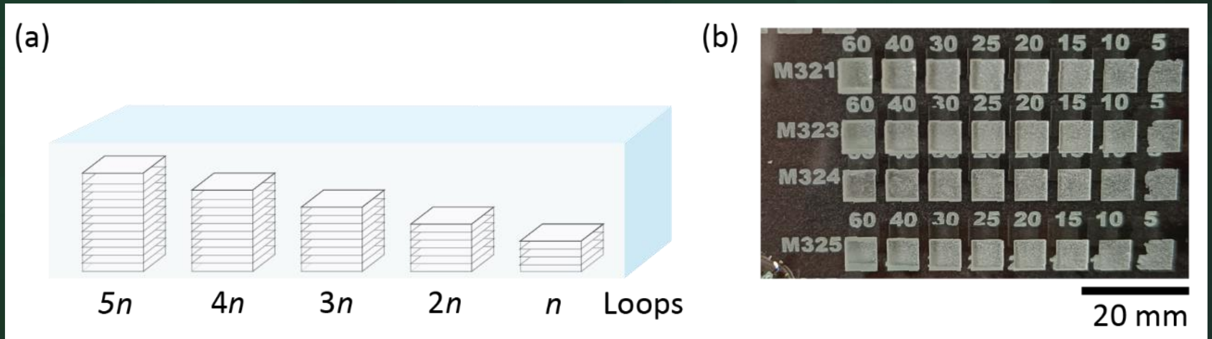
/ If the material is transparent – BUM can be used.

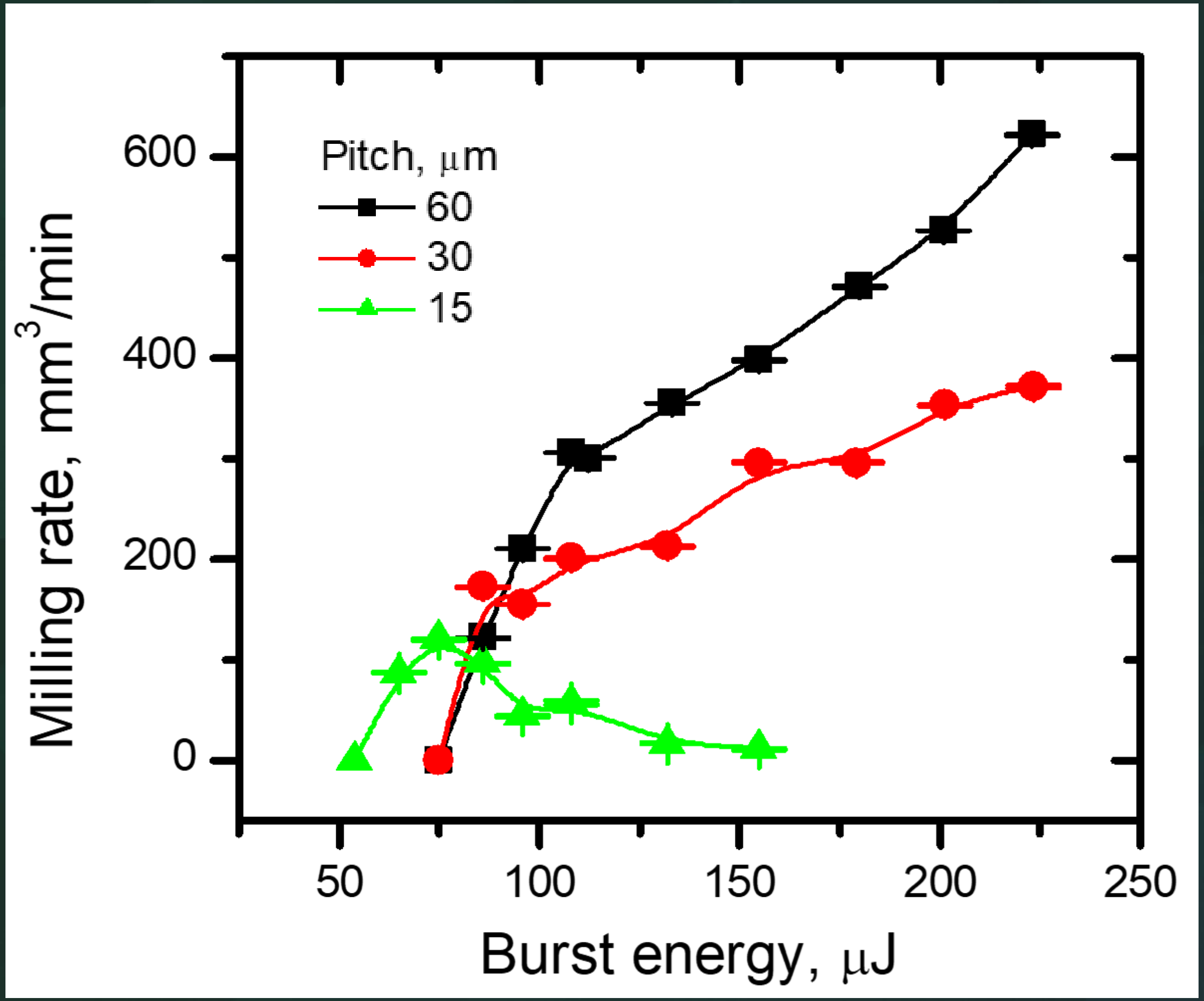


Courtesy of FTMC.

Bottom-up Milling (BUM) – Further Increase in Ablation Rate

- For efficient milling in Bottom-up Milling mode, Z pitch (slicing) is crucial;
- Optimisation of Z pitch: scanning of multiple layers with different Z pitch values;
- MHz+GHz burst (GHz = 24, MHz = 2) resulted in **619.5 mm³/min** removal rate in soda-lime glass. **119.8 times** higher than TDM in single-pulse mode.





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Courtesy of FTMC.

Task No 4

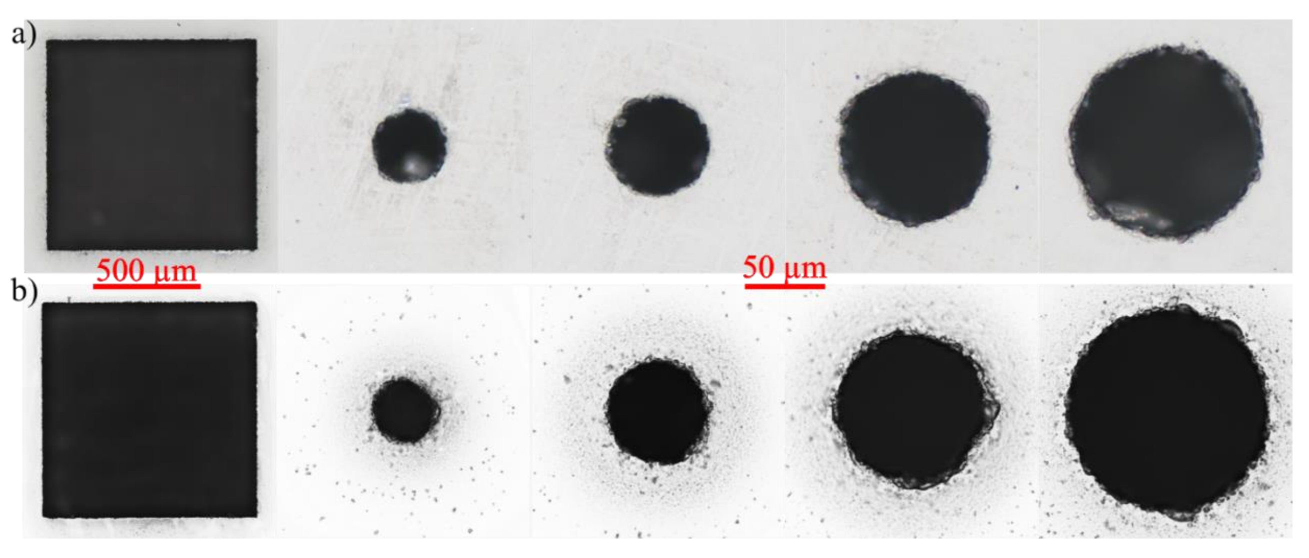
Processing geometries with low-tapers

Bottom-up Milling (BUM) – Low Degree Taper Geometries

- Low taper holes can be formed in the material since ablation debris do not accumulate in the ablation area;
- Taper < 1 deg. can be achieved for holes in Ø40-120 µm range.

Dimensions	1×1 mm^2	Ø40 µm	Ø60 µm	Ø90 µm	Ø120 µm
Angle, TDM	**8.0**	**6.7**	**7.2**	**7.9**	**8.6**
Angle, BUM	**2.5**	**0.4**	**0.6**	**1.0**	**0.4**

BF33 glass



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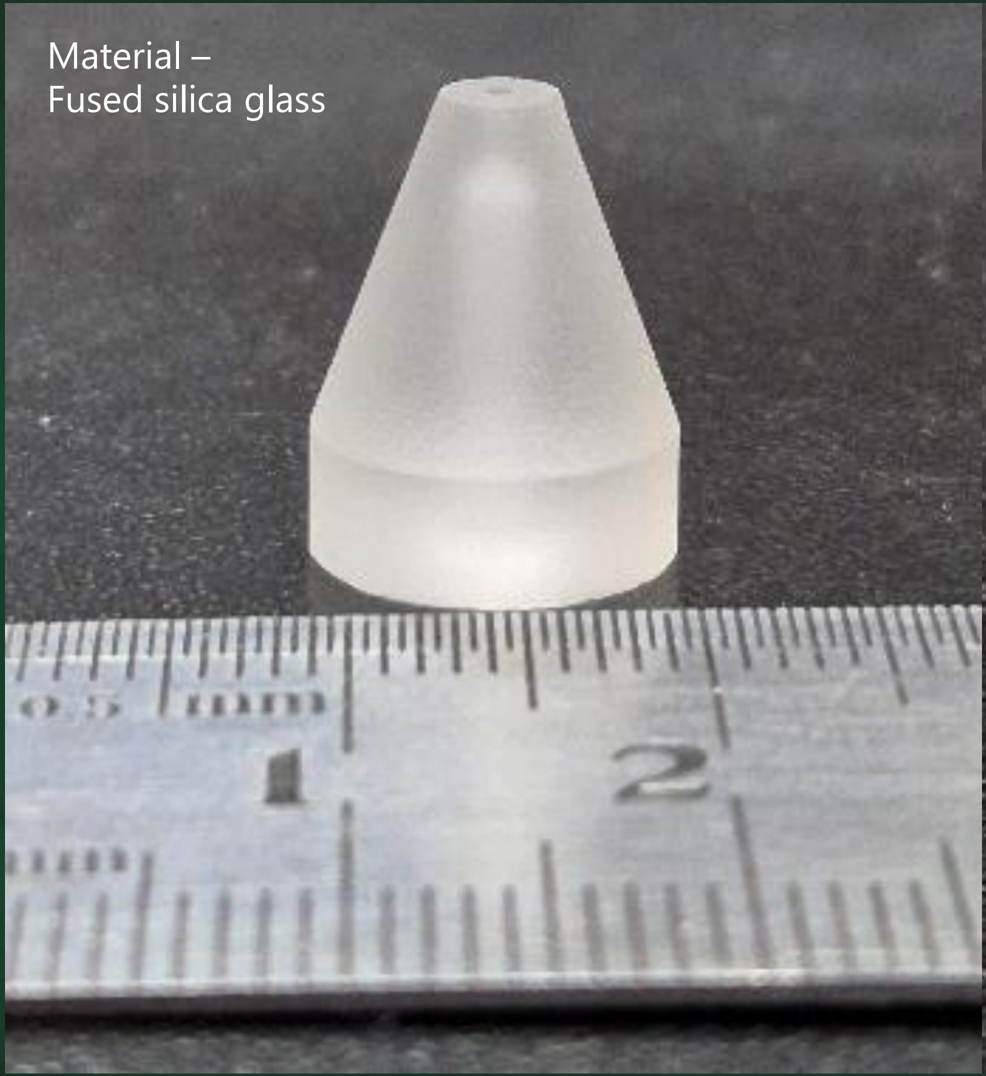
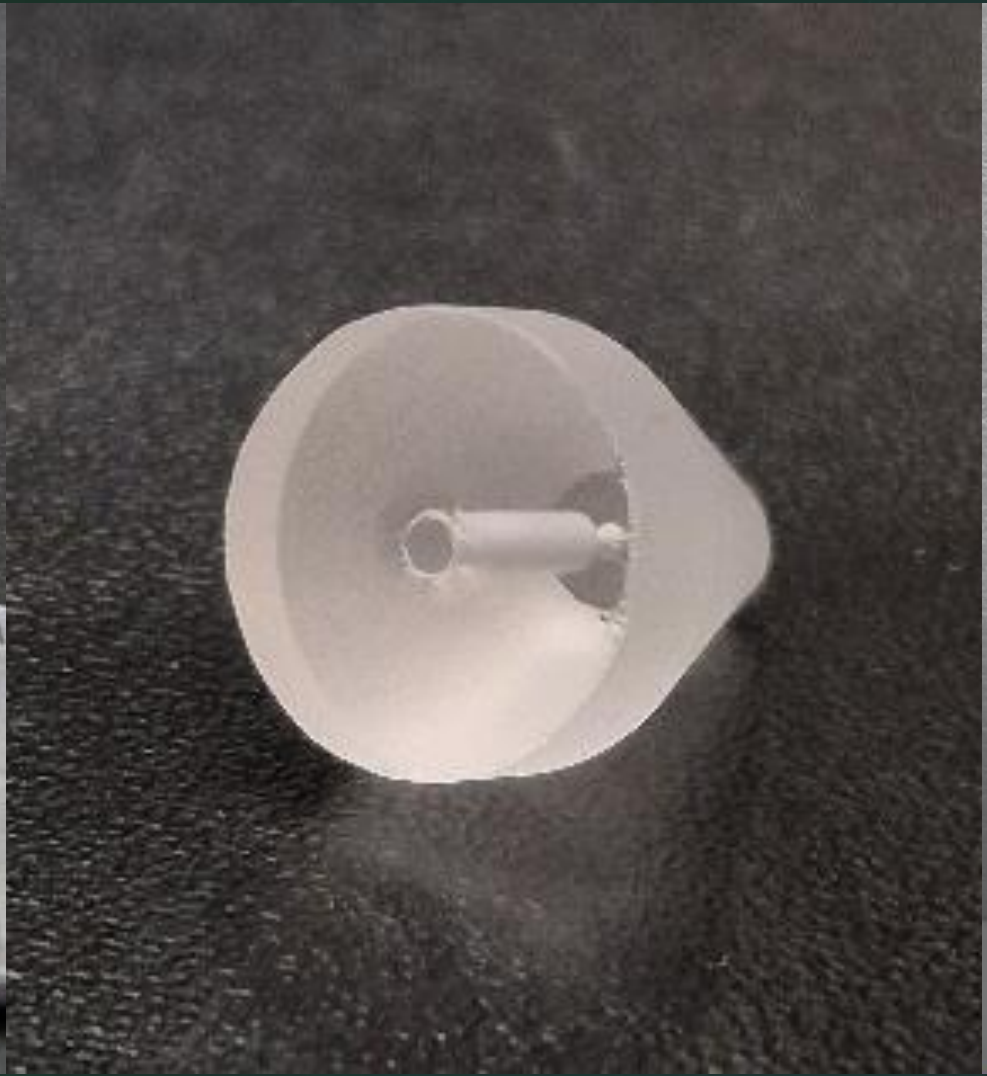
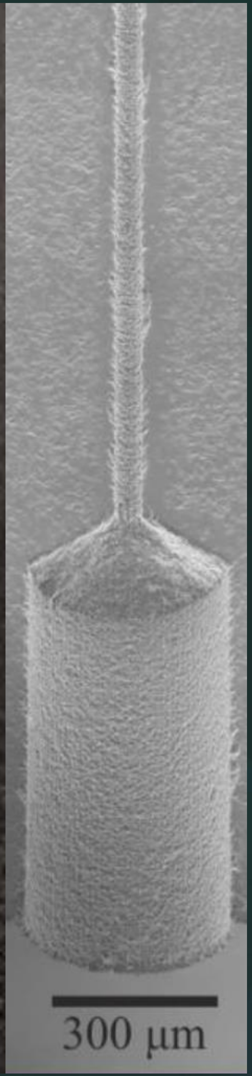
Courtesy of FTMC.

Bottom-up Milling (BUM) – Nozzle Fabrication

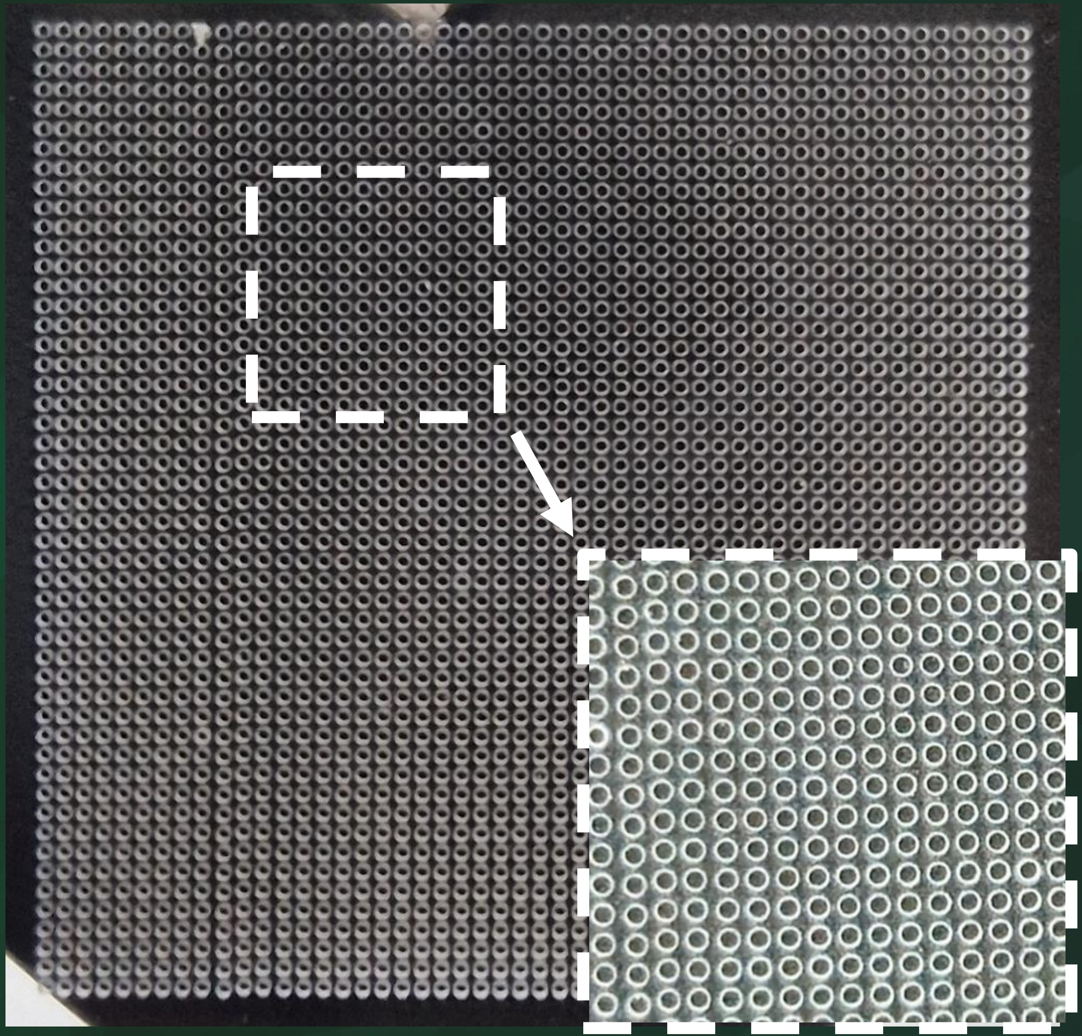






Aspect ratio of 1:32, without the need of chemical etching. Courtesy of FTMC.

Bottom-up Milling (BUM) – Through-Glass Vias Fabrication



Low taper Ø200 µm through holes. Aspect ratio of 1:3 (higher is possible). Courtesy of FTMC.

Low taper Ø60 µm through holes
Aspect ratio of 1:12

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Task No 5

Drilling of high aspect ratio holes

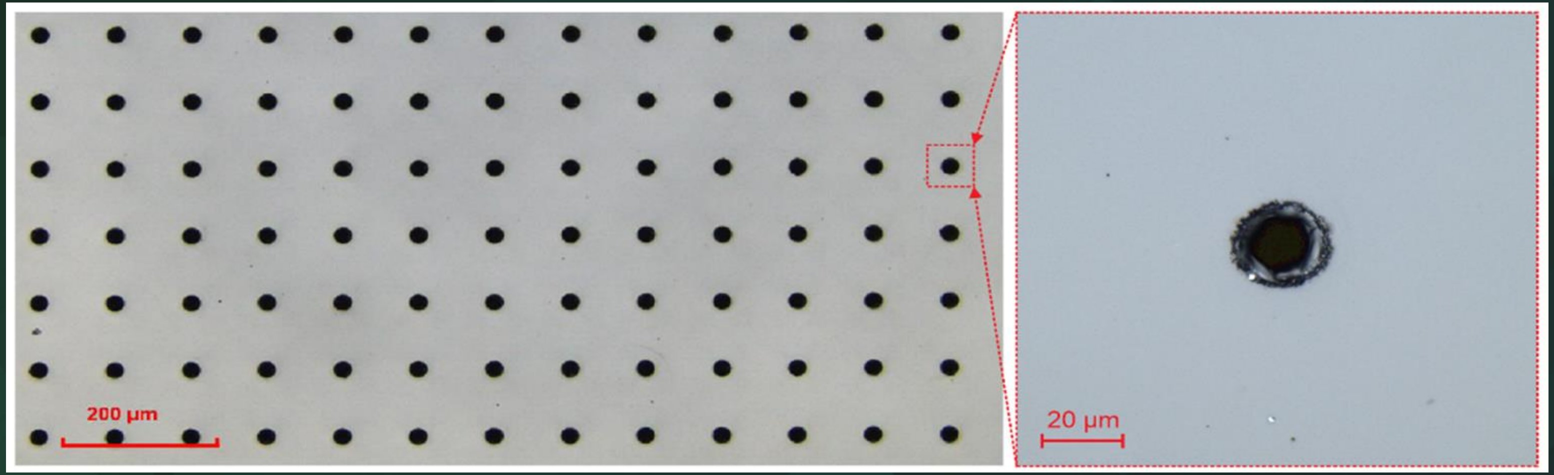
Long GHz Burst in Fabricating Through Glass Vias

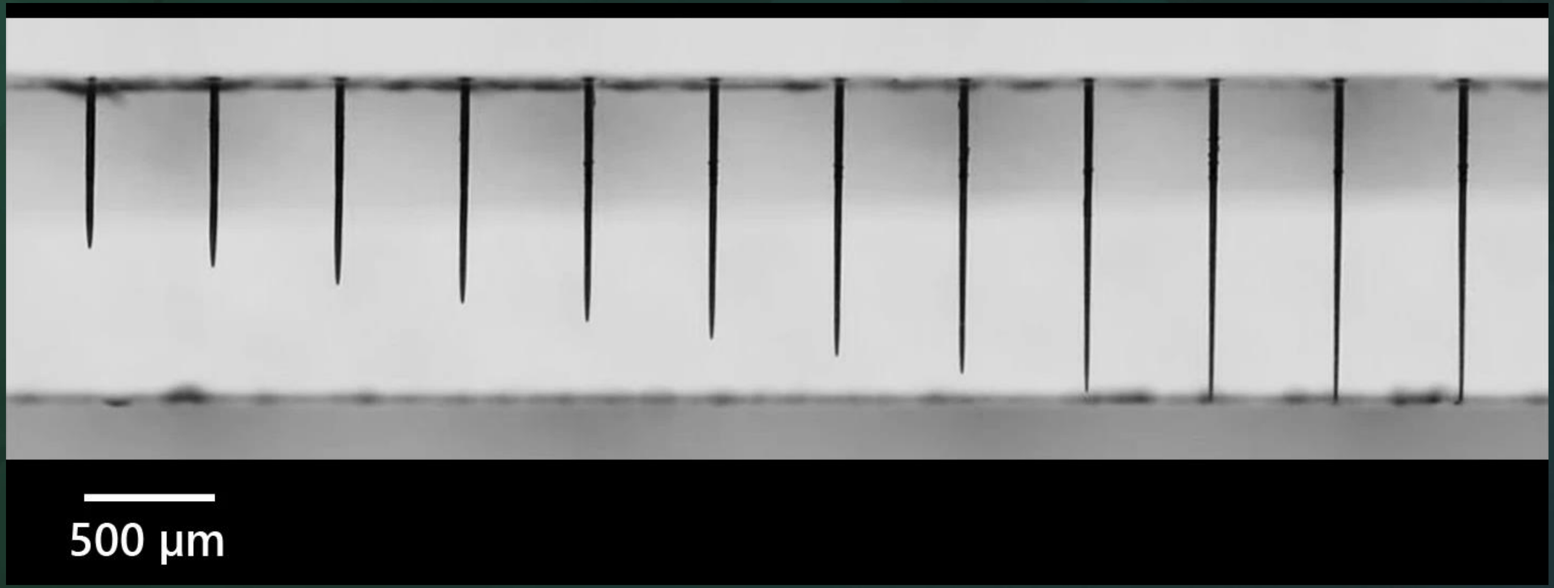
/ GHz bursts initiate self-focusing in the glass volume;

/ Achievable aspect ratio – 1:80;

/ Processing time – 1 hole per 500 ms;

/ Samples cleaned





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Courtesy of Akoneer.

Task No 6

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Your task is welcomed

In all tasks the same laser was employed

FemtoLux 30

30 W @ 1030 nm

High Energy (up to 1 mJ) available

Dry cooling

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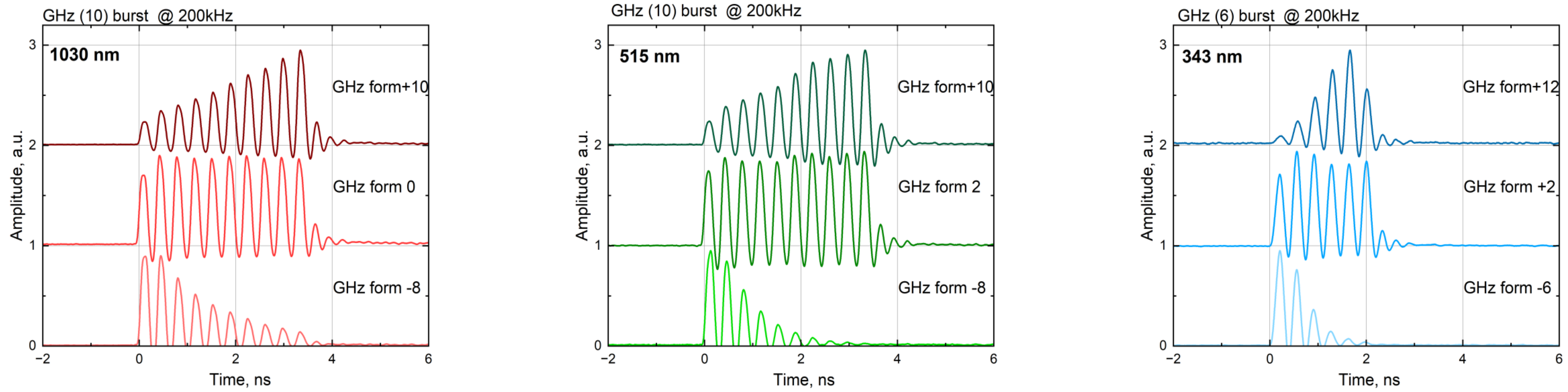
GHz/MHz+GHz burst mode in 515/343 nm

Upcoming



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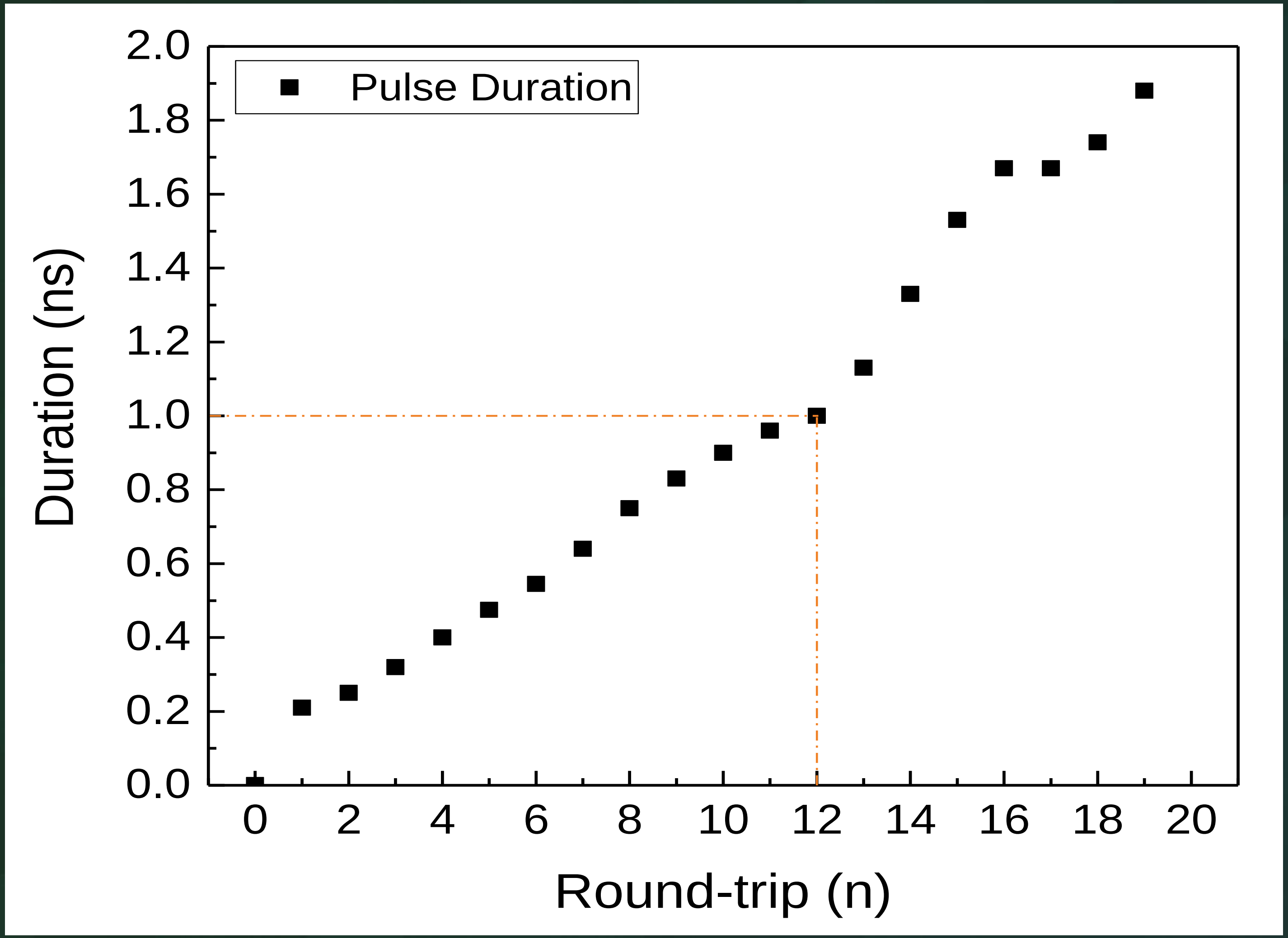
Wide pulse tunability – from fs to ns

Upcoming



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How can these features improve your processes?

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