High Aspect Ratio Through Glass Vias (TGVs)

Faculty:
Dr. Fuhan Liu
Dr. Mohanalingam Kathaperumal
Prof. Madhavan Swaminathan
Prof. Rao R. Tummala

Student:
Rui Zhang

Outline

- Goals & Objectives
- Technical Approach
- Results & Key Accomplishments
- Comparison with Prior Art
- Schedule
- Summary

Goals and Objectives

- The objective of this research is to investigate and develop high aspect ratio and small opening through glass vias with low surface roughness for high density interconnects for 2.5D and RF applications

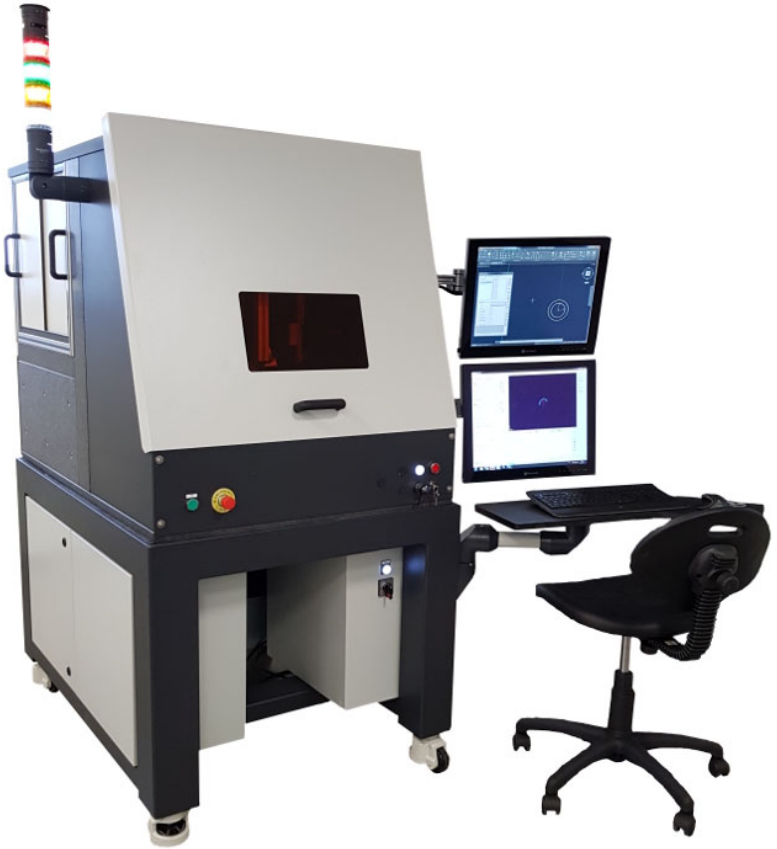
- The goal is to fabricate high quality high throughput TGVs with aspect ratios larger than 2:1 (up to 10:1) in 300 μm glass

Technical Approach

- Ultra-short pulse (femtosecond) laser ablation

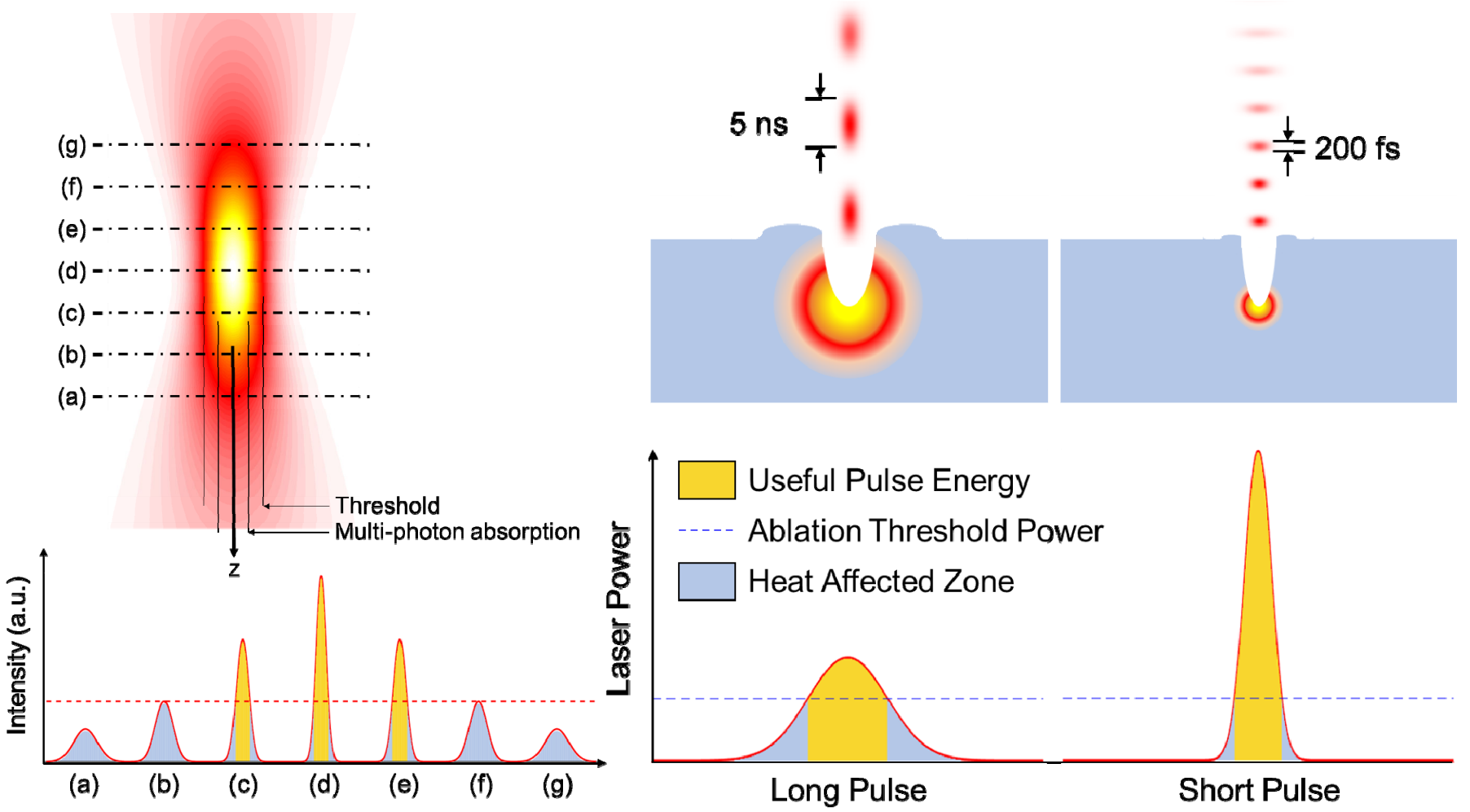
- OPTEC Femtosecond Laser Micro-machining System
  - Max Power: 4 W
  - Wavelength: 1.03 μm
  - Minimum Pulse Duration: 221 fs
  - Effective on polymer, copper, steel, FR-4, silicon, glass, etc.

- Parameters to be optimized
  - Power, frequency, repetition, speed, drilling mode
- Glass: 300 μm AGC glass



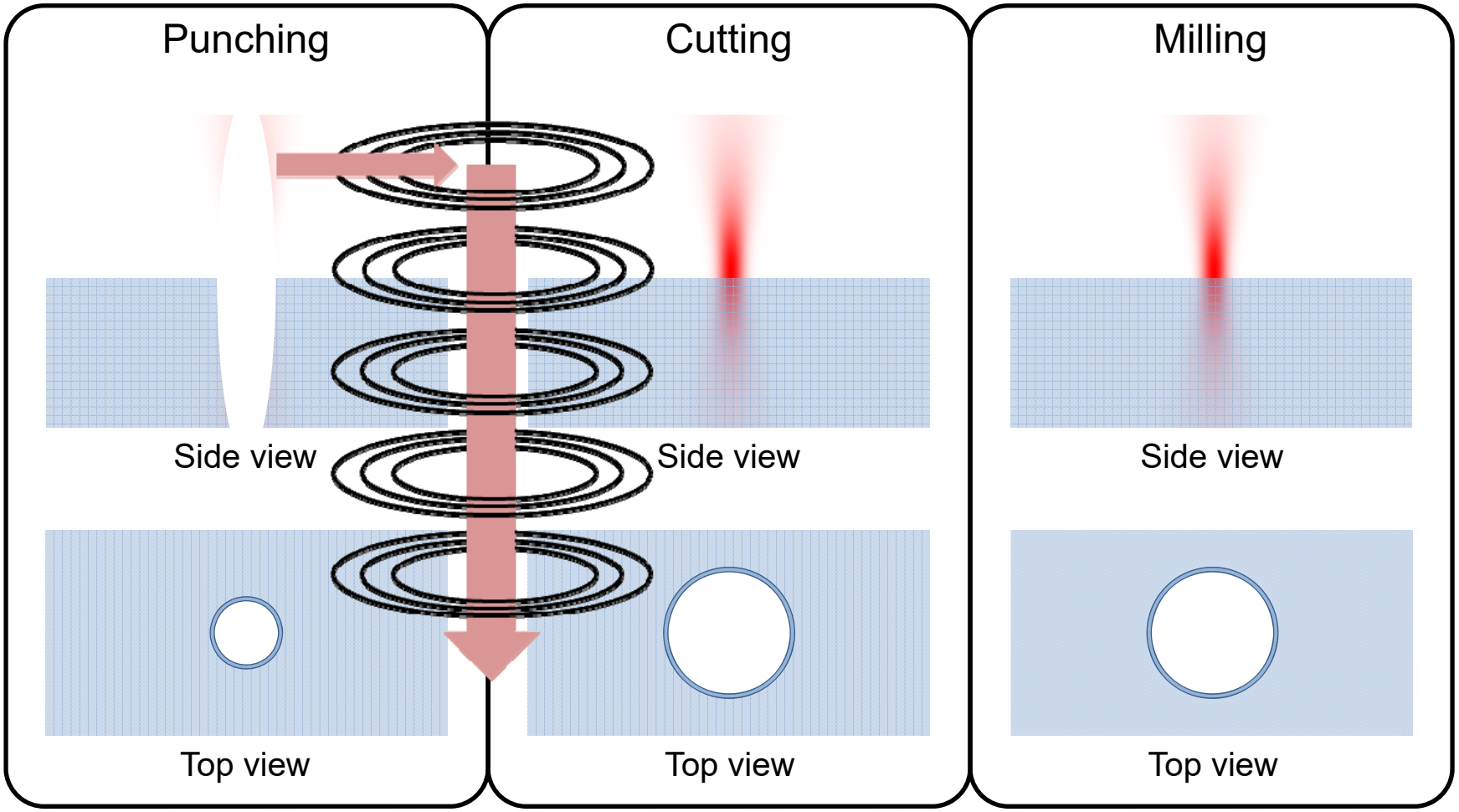
Technical Approach (cont.)

- Ultra-short pulse (femtosecond) laser ablation



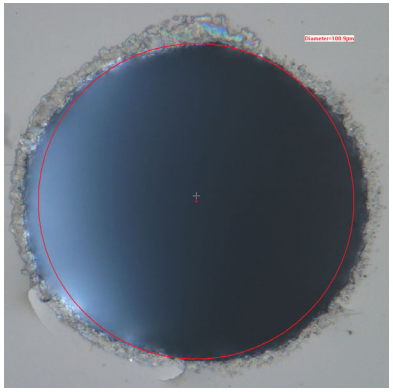
Technical Approach (cont.)

- Ultra-short pulse (femtosecond) laser ablation

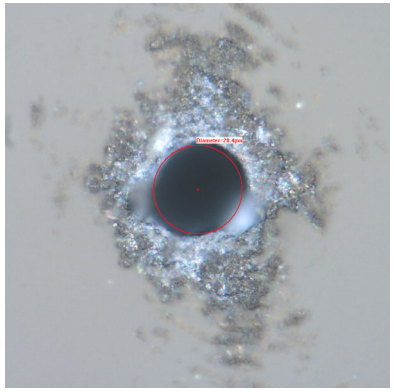


Results & Key Accomplishments

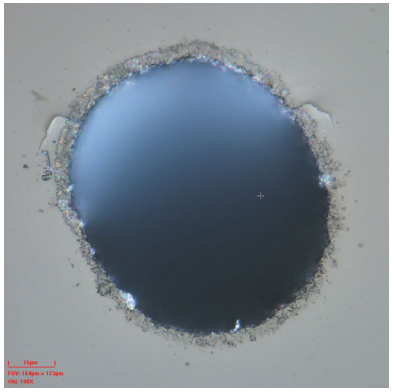
- Front side drilling
  - Standard TGV: 100 µm
  - Smallest TGV: 80 µm



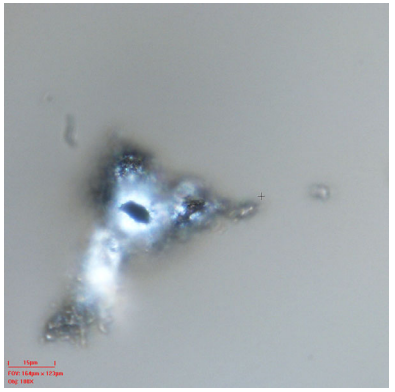
Top opening
100.9 µm



Bottom opening
28.4 µm



Front opening
78.8 µm

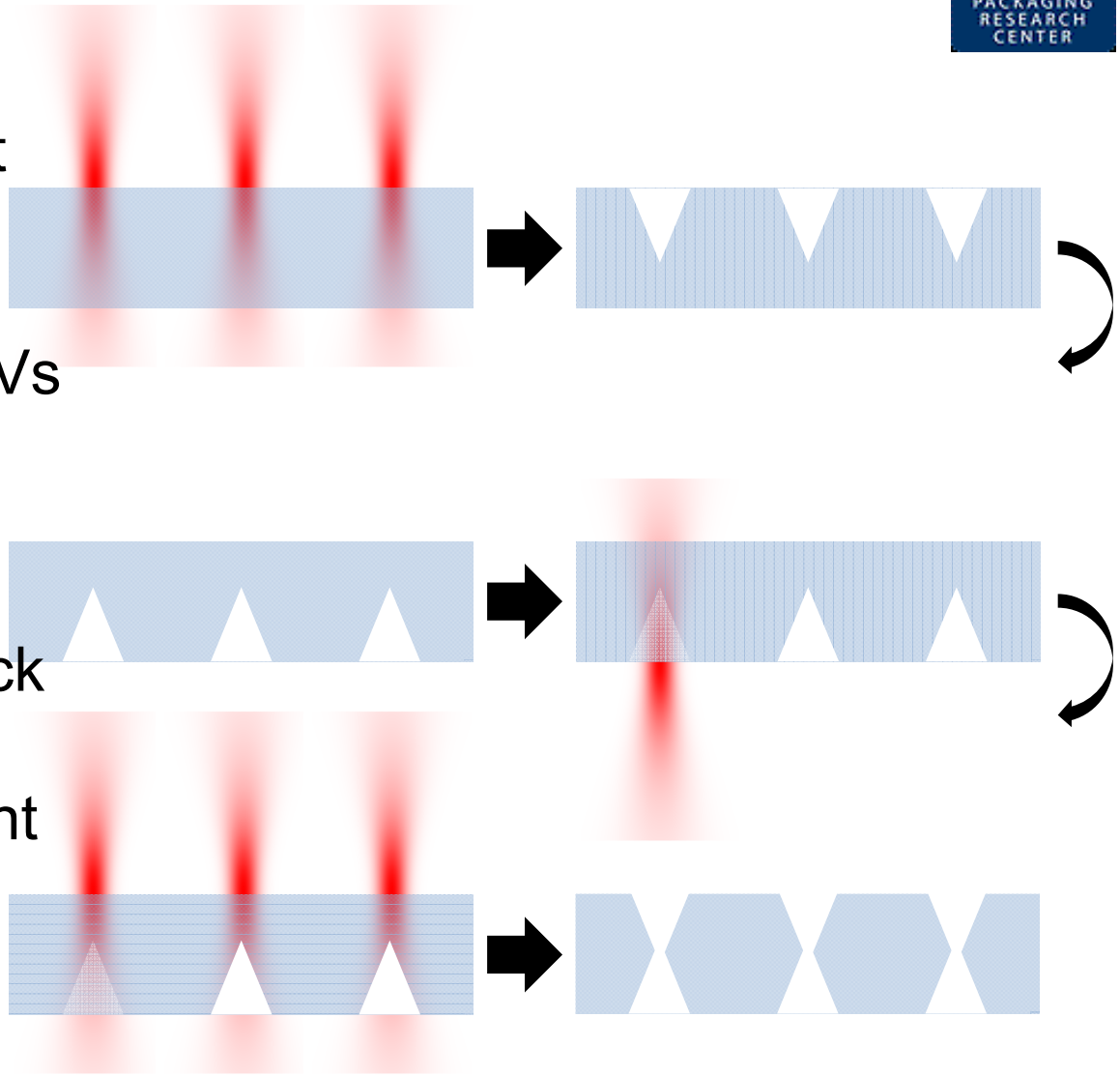


Back opening
10.2 µm

- Moving laser focal plane down while drilling
- Sidewall angle ~ 83°
- Via < 80 µm could NOT be opened by front side drilling due to the taper

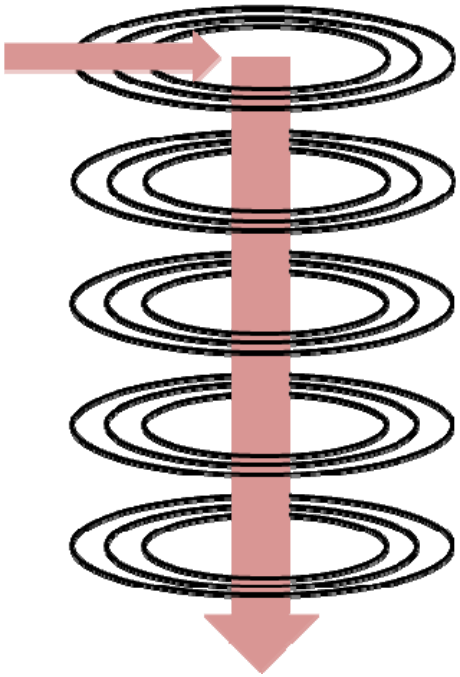
Results & Key Accomplishments (cont.)

- Double side drilling
  - Glass is transparent
  - Front side drilling alone could not achieve smaller TGVs
- Process
  - Front side drilling
  - Flipping the glass
  - Focusing on the back for alignment
  - Focusing on the front for laser ablation
  - Front side drilling

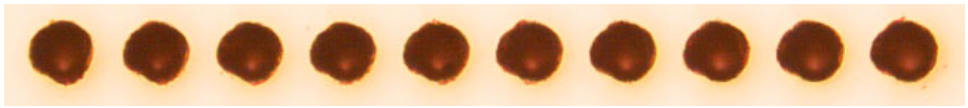


Results & Key Accomplishments (cont.)

- Double side drilling

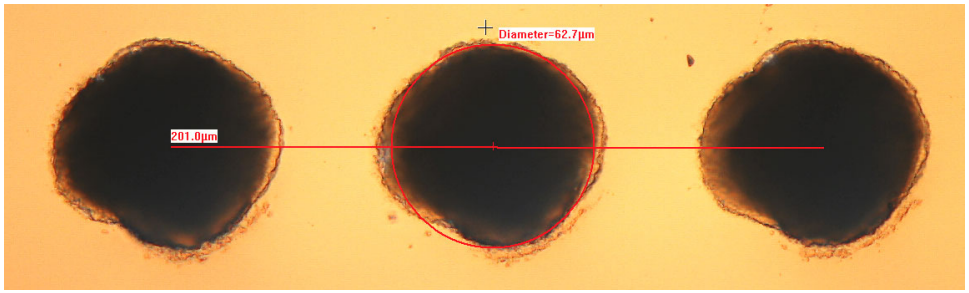


Power increasing as laser focusing deeper into the glass



Top view

Via opening inside the glass

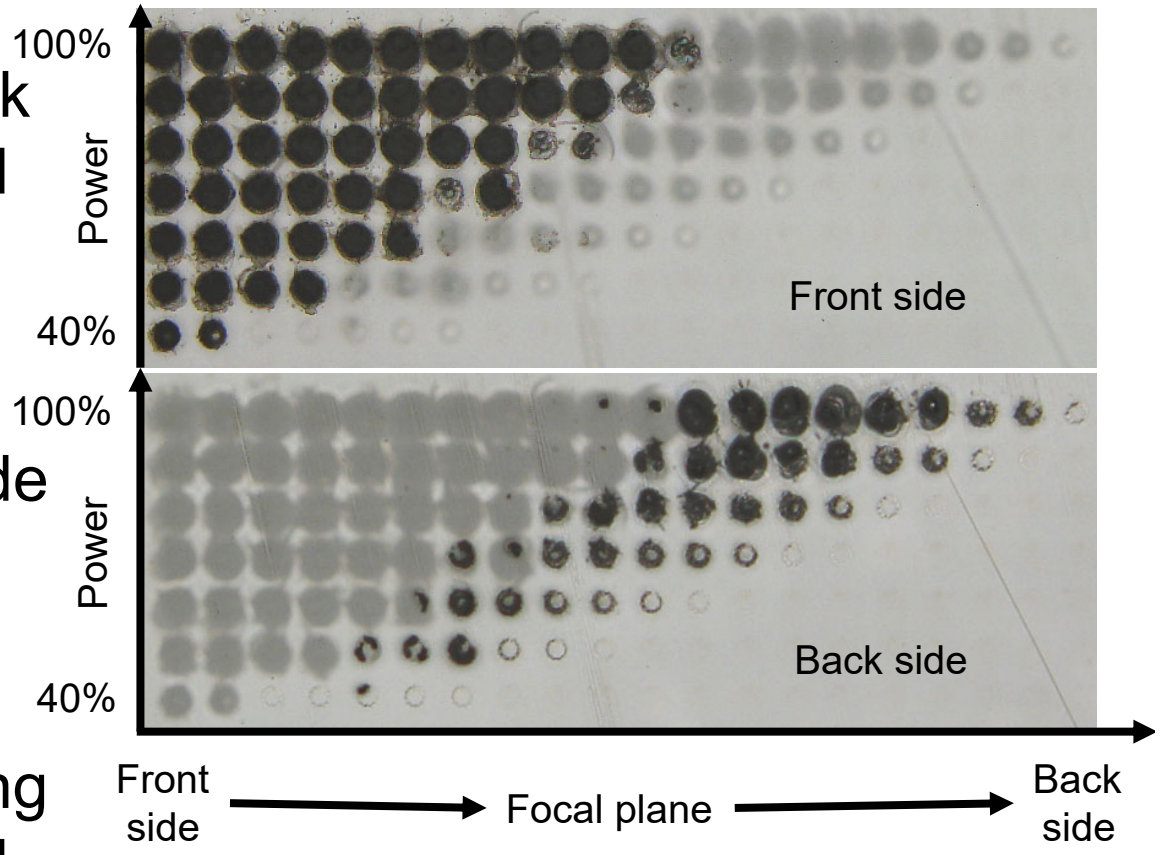


Diameter: 62.7 µm
Pitch: 100 µm

- 60 µm TGVs achieved in a 300 µm glass
- Optimization needed for smaller TGVs

Results & Key Accomplishments (cont.)

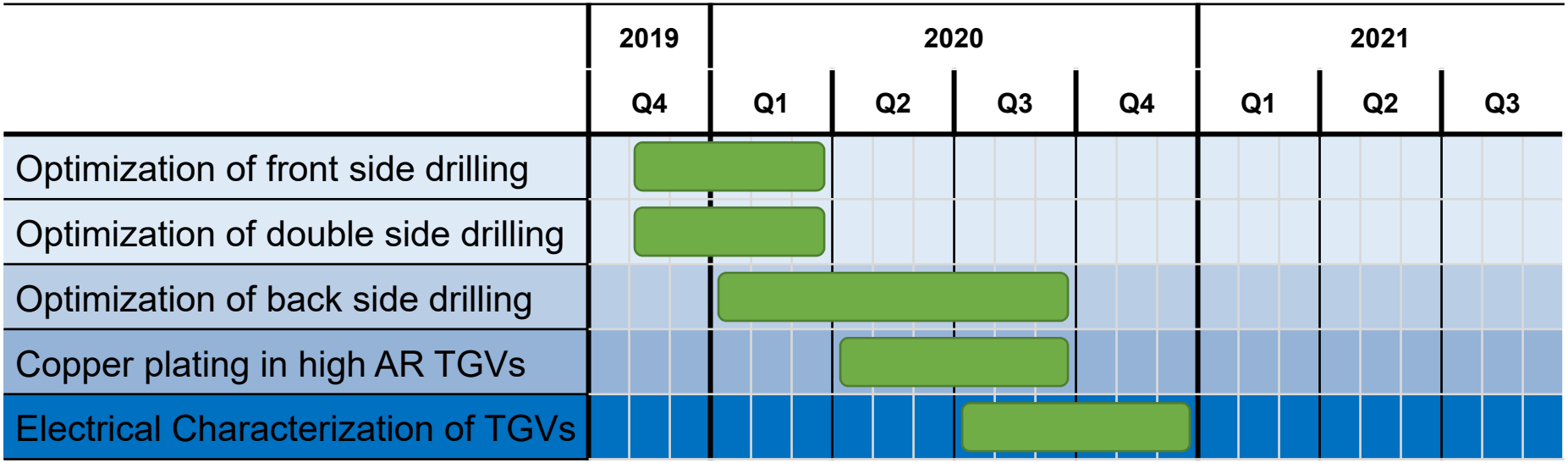
- Back side drilling
  - Glass is transparent
  - Focusing on the back side of the glass and drilling upwards are possible
  - Compared to front side drilling, back side drilling avoids laser power diffusion from the taper
  - Extremely challenging
  - Optimization needed



Comparison with Prior Art

- 60 μm TGVs with 100 μm pitch in 300 μm glass, comparable to state-of-the-art laser drilling TGVs
  - Mechanical: 4:1 and rough
  - Chemical: 10:1 and slow
  - Thermal: 7:1 on special glass
  - Hybrid: 3:1
- Near Infrared laser enables back side drilling and aspect ratio could be improved further than the current value (AR 5:1) with further optimization

Schedule


2019
2020
2021
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Optimization of front side drilling
Optimization of double side drilling
Optimization of back side drilling
Copper plating in high AR TGVs
Electrical Characterization of TGVs

Summary

- Process optimization for laser ablation with minimum heat affected zone and debris
- 80 μm TGVs using front side drilling achieved
- 60 μm TGVs using double side drilling achieved

- Future work
  - Shape profile characterization
  - Optimization of back side drilling
  - Copper plating of high AR TGVs