Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Shedding Light on Pulse Bursts

APPOLO Workshop

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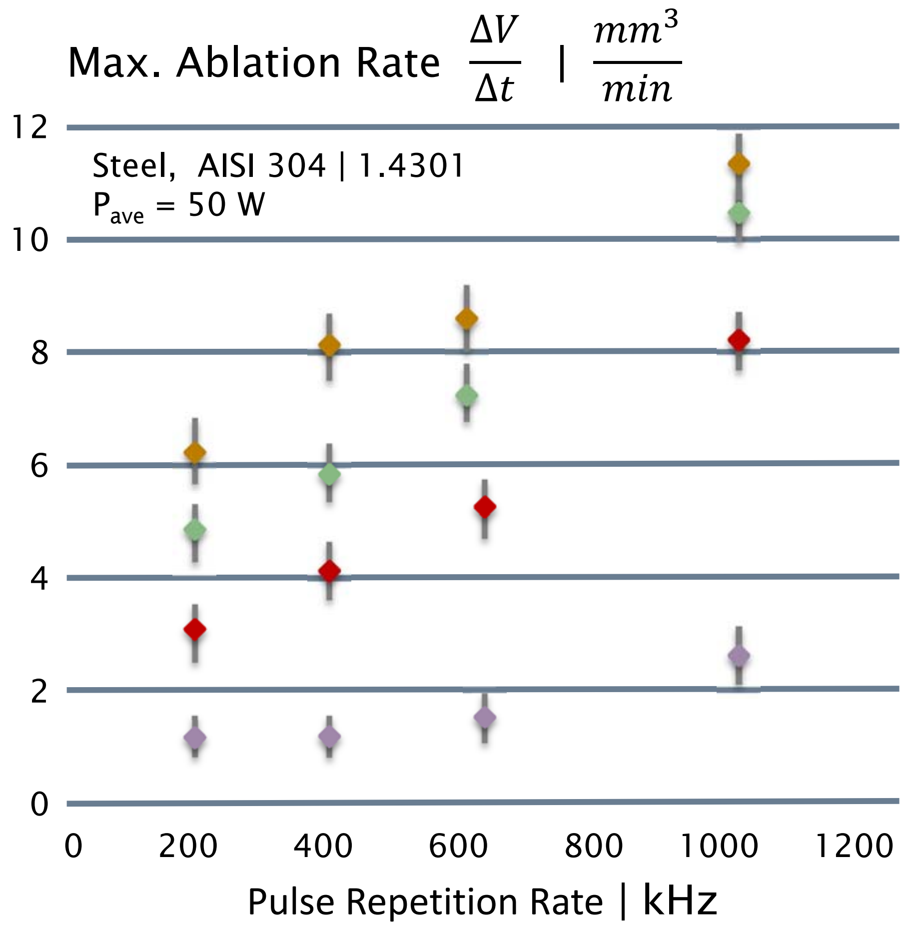
Outline

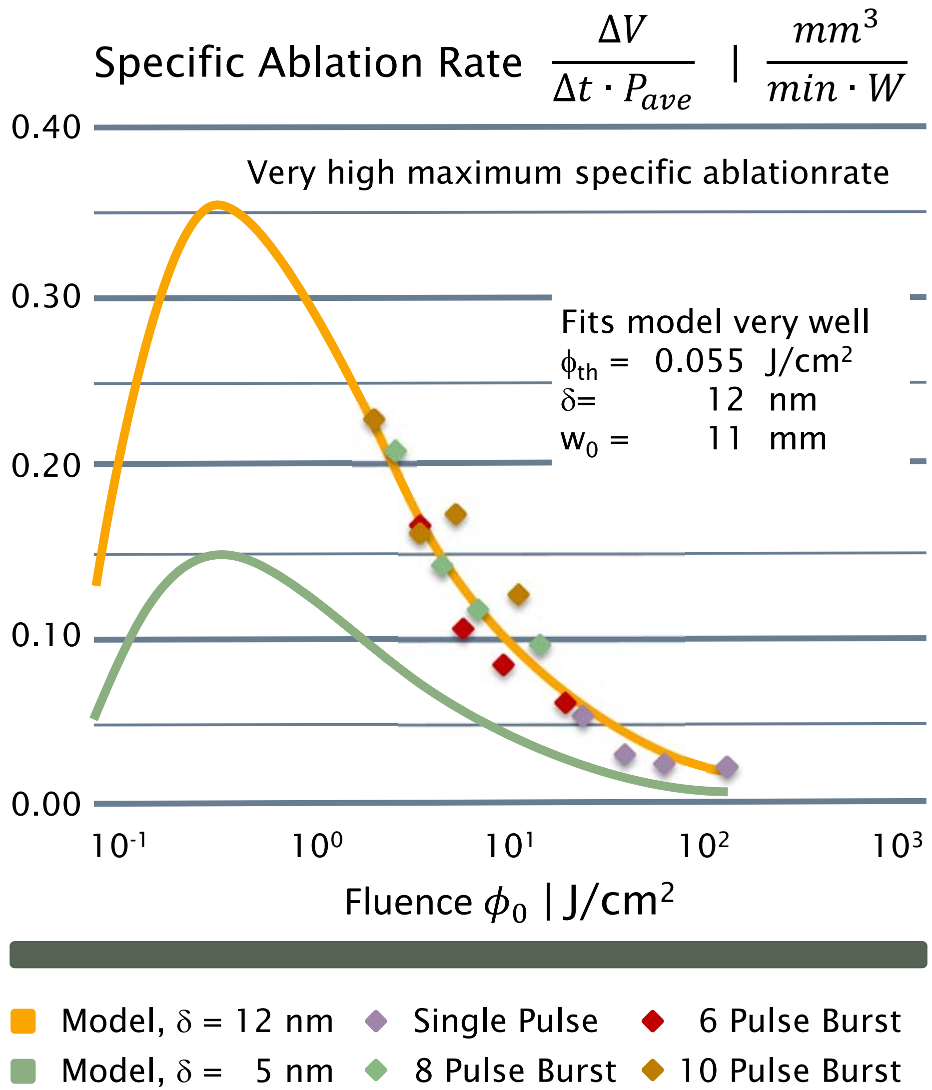
Shedding Light on Pulse Bursts

- Introduction
- Generation of Pulse Bursts
- Applying Pulse Bursts
  - Steel
  - Copper
- Summary and Outlook

Introduction

Introduction



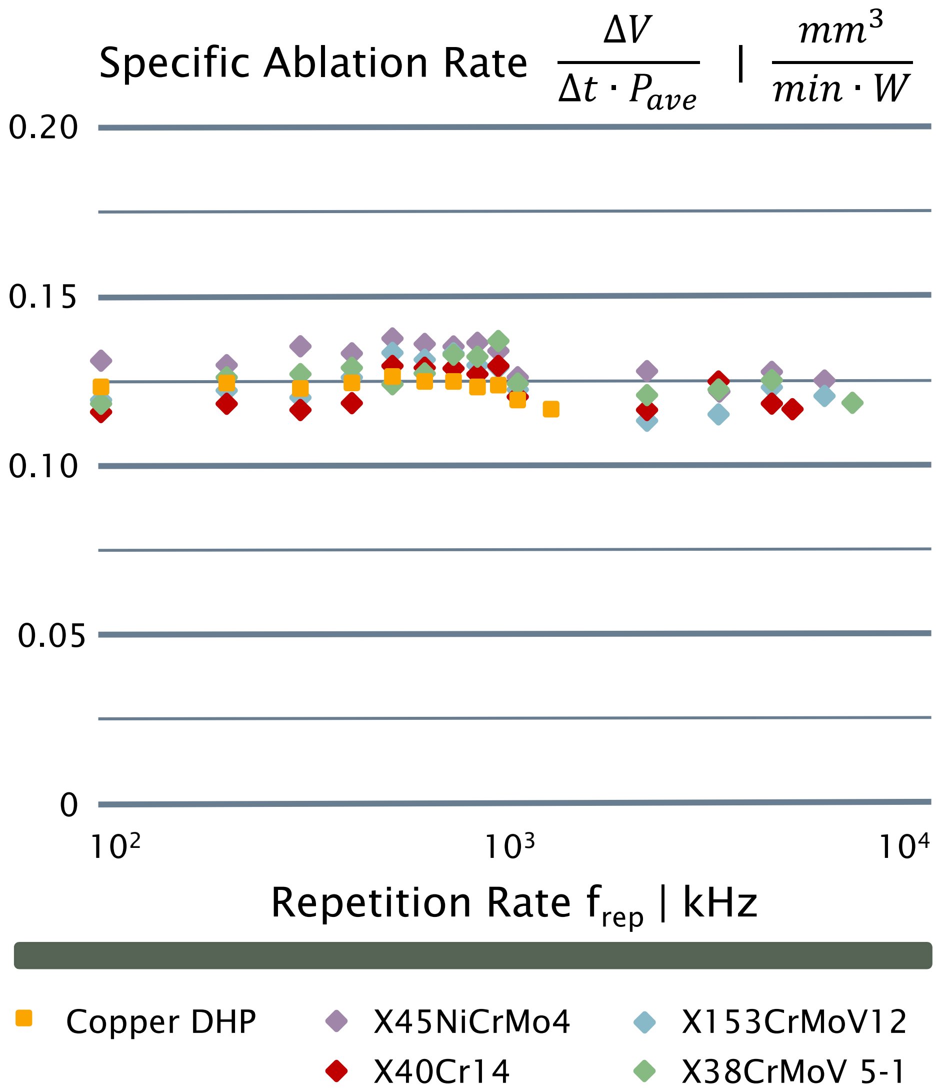


KNAPPE, R; HALOUI, H.; SEIFERT, A.; NEBEL, A.: “Scaling ablation rates for picosecond lasers using burst micromachining“, SPIE 7585-16 (2010)

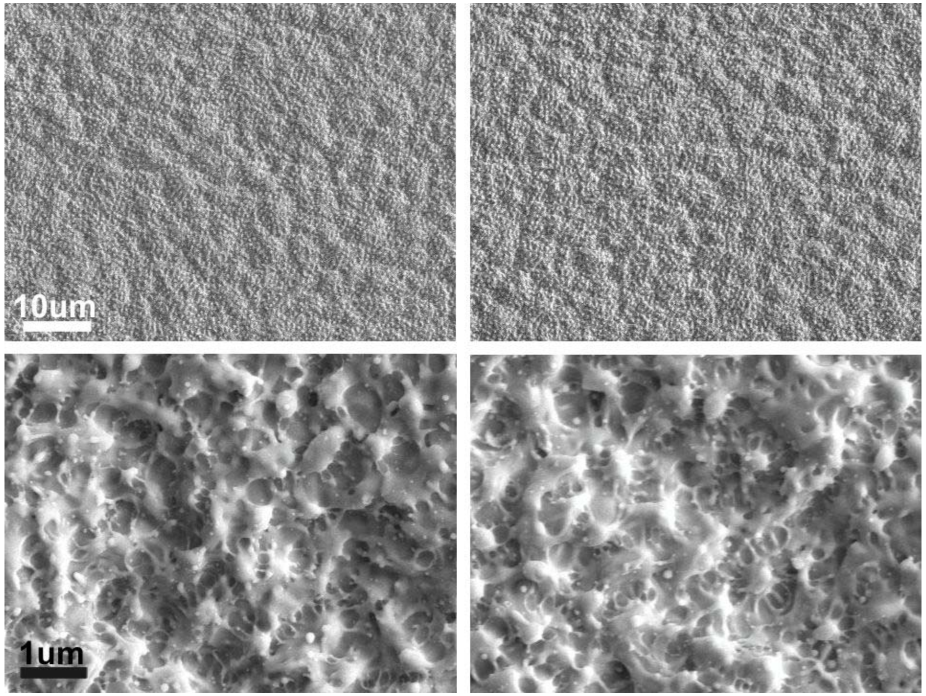
Introduction

Repetition rate	f_{rep}	4.1	MHz
Average Power	P_{ave}	25.6	W
Pitch:		14.5	µm
Scan speed	v_{scan}	59.5	m/s
		2233	layers

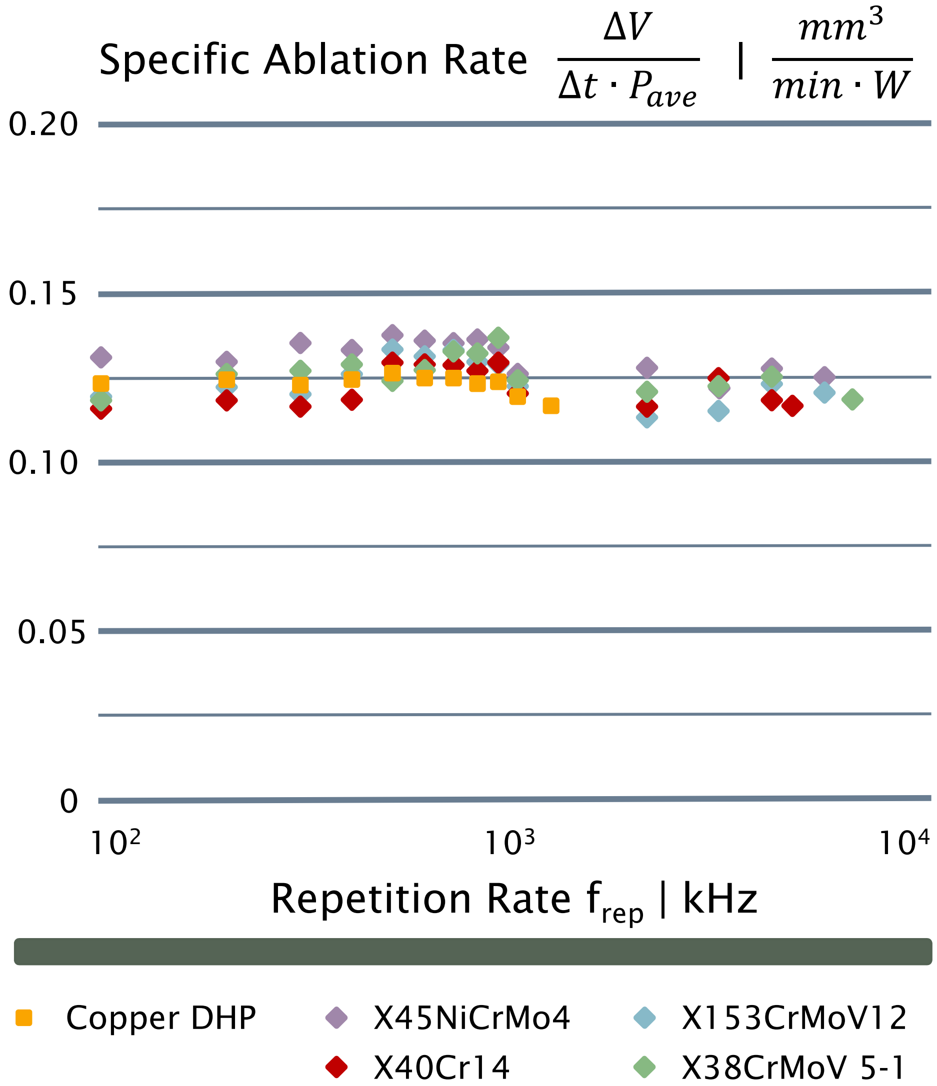
JAEGGI, B. et al.: "High-throughput and high-precision laser micromachining with ps-pulses in synchronized mode with a fast polygon line scanner", Proc. SPIE 8967, (2014)



Introduction



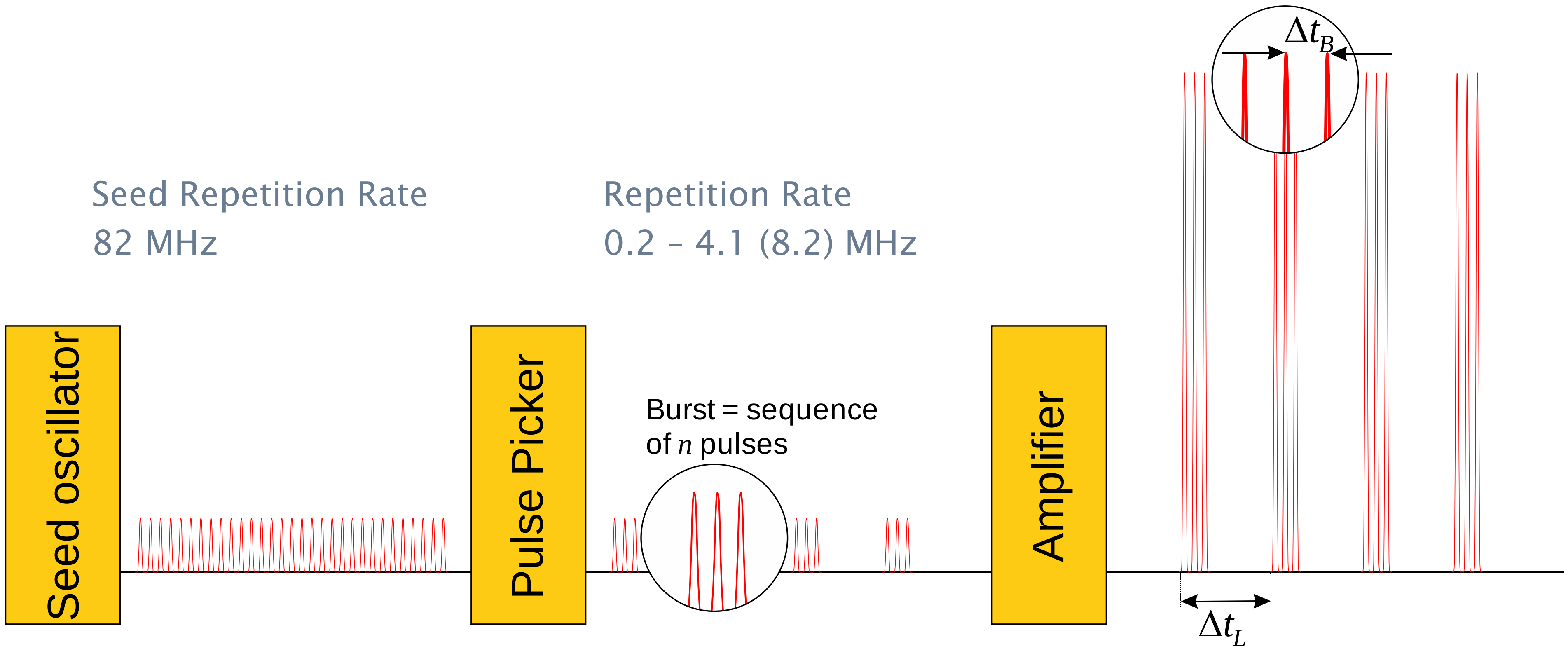
P_{ave}	12 W	42 W
f_{rep}	2.05 MHz	6.83 MHz



Generation of Pulse Bursts

Generation of Pulse Bursts

Mode-locked ultrafast Laser Beam Source | Burst mode



Applying Pulse Bursts

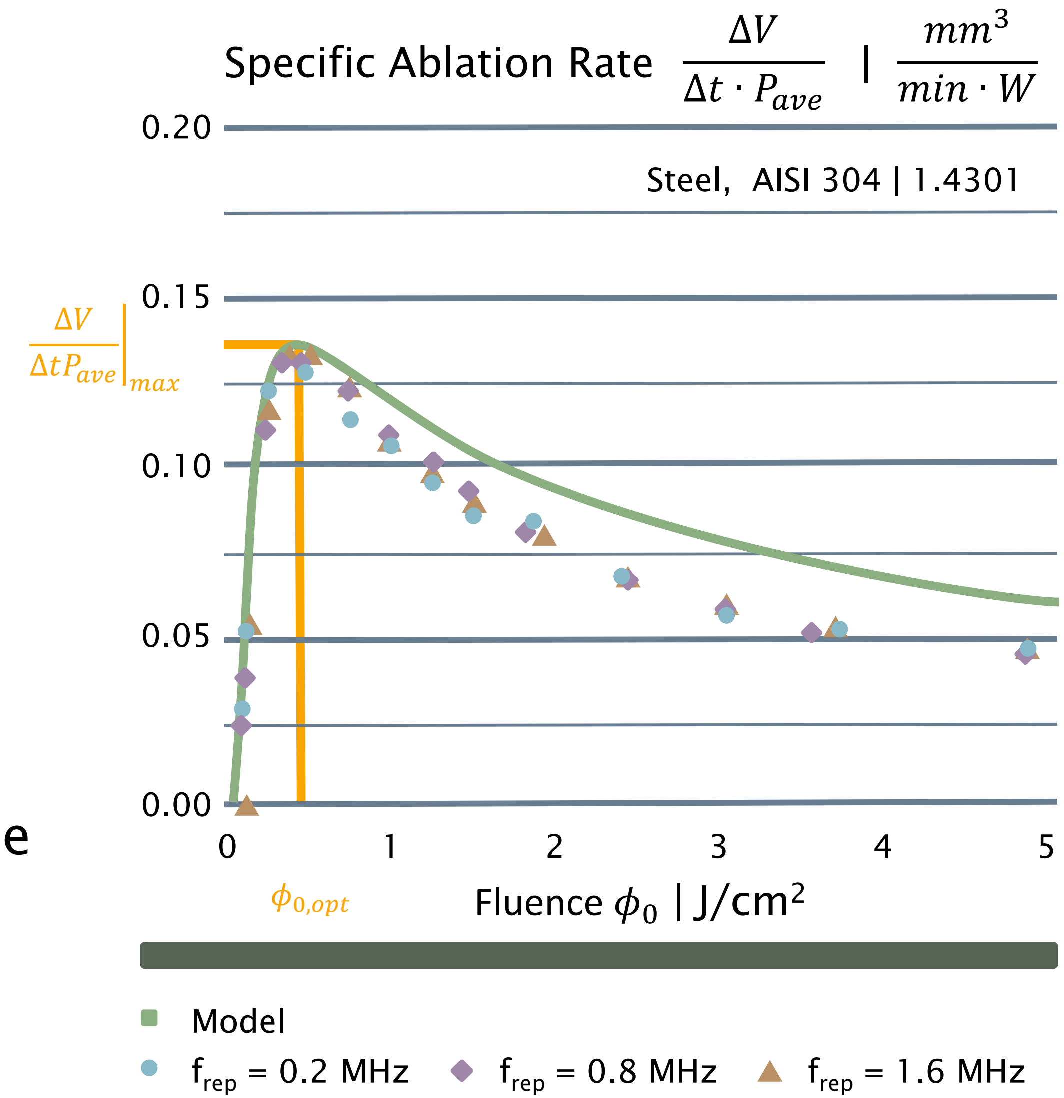
Steel

Applying Pulse Bursts

Basic Ablation Model: Gaussian Beam

- material parameters
  threshold fluence ϕ_{th}
  energy penetration depth δ
- specific ablation rate
  $$\frac{\Delta V}{\Delta t \cdot P_{ave}} = \frac{1}{2} \cdot \frac{\delta}{\phi_0} \cdot ln^2\left(\frac{\phi_0}{\phi_{th}}\right)$$
- optimum fluence
  $$\phi_{0,opt} = e^2 \cdot \phi_{th}$$
- maximum specific ablation rate
  $$\left.\frac{\Delta V}{\Delta t \cdot P_{ave}}\right|_{max} = \frac{2}{e^2} \cdot \frac{\delta}{\phi_{th}}$$

Shedding Light on Pulse Bursts

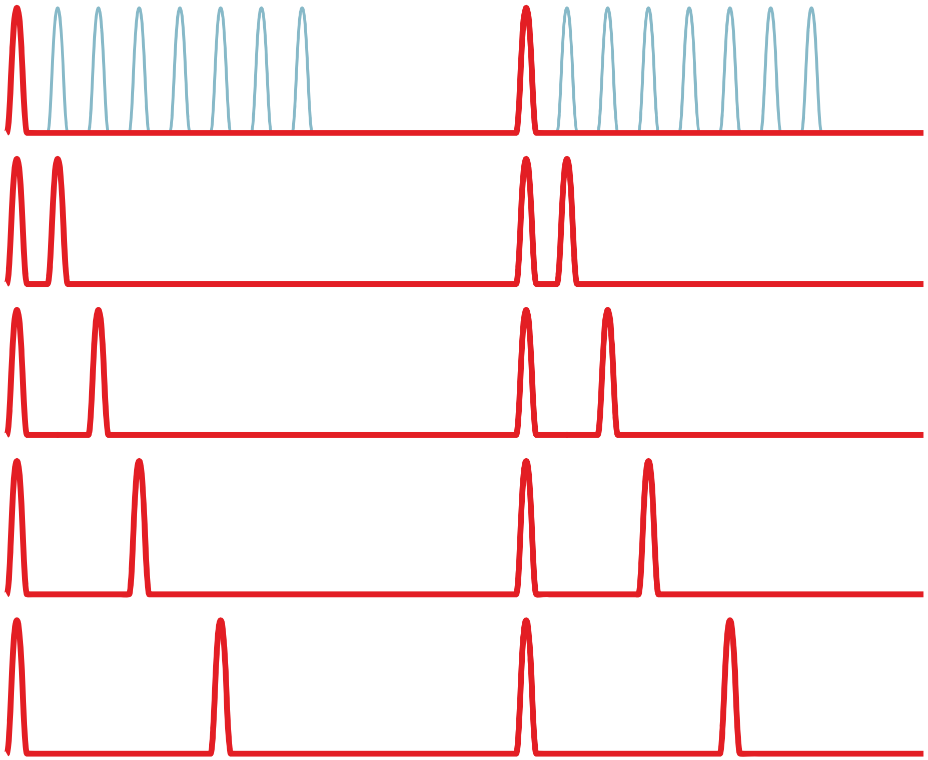


Applying Pulse Bursts

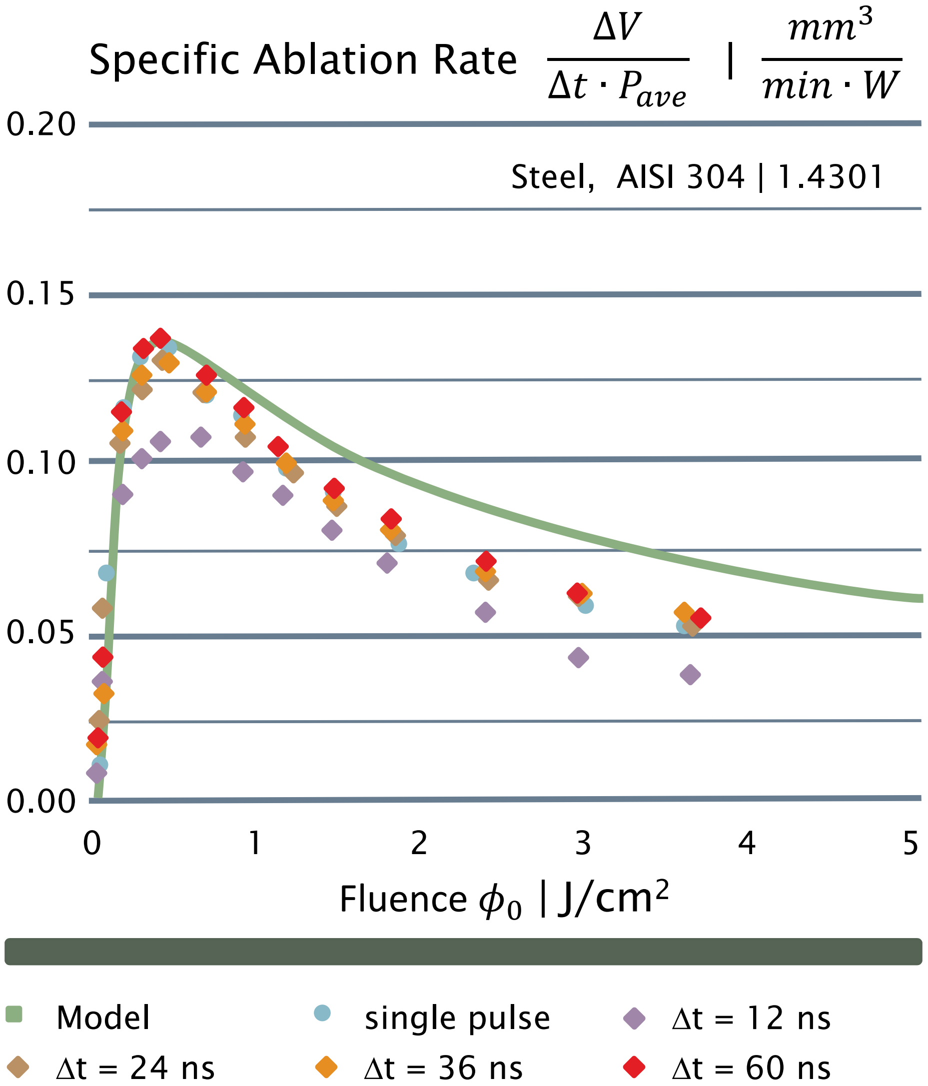
Shedding Light on Pulse Bursts

Applying Pulse Bursts

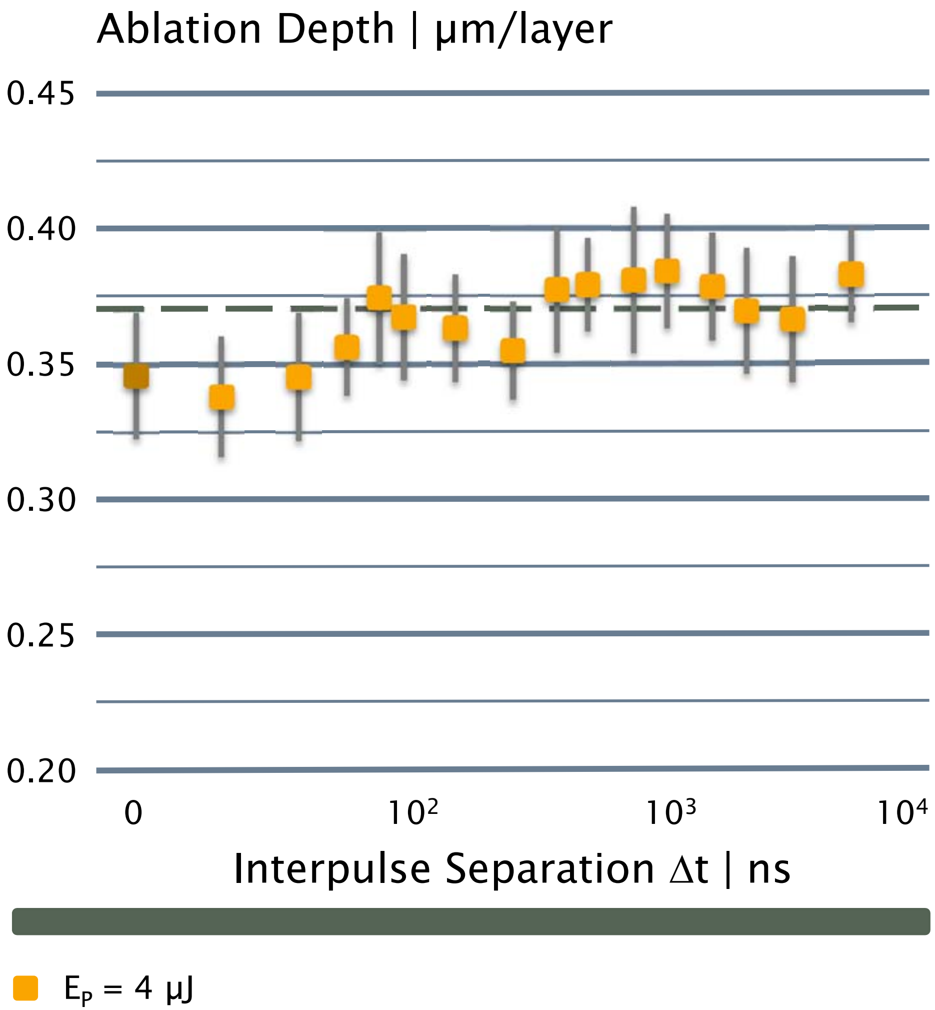
- varying the inter pulse distance

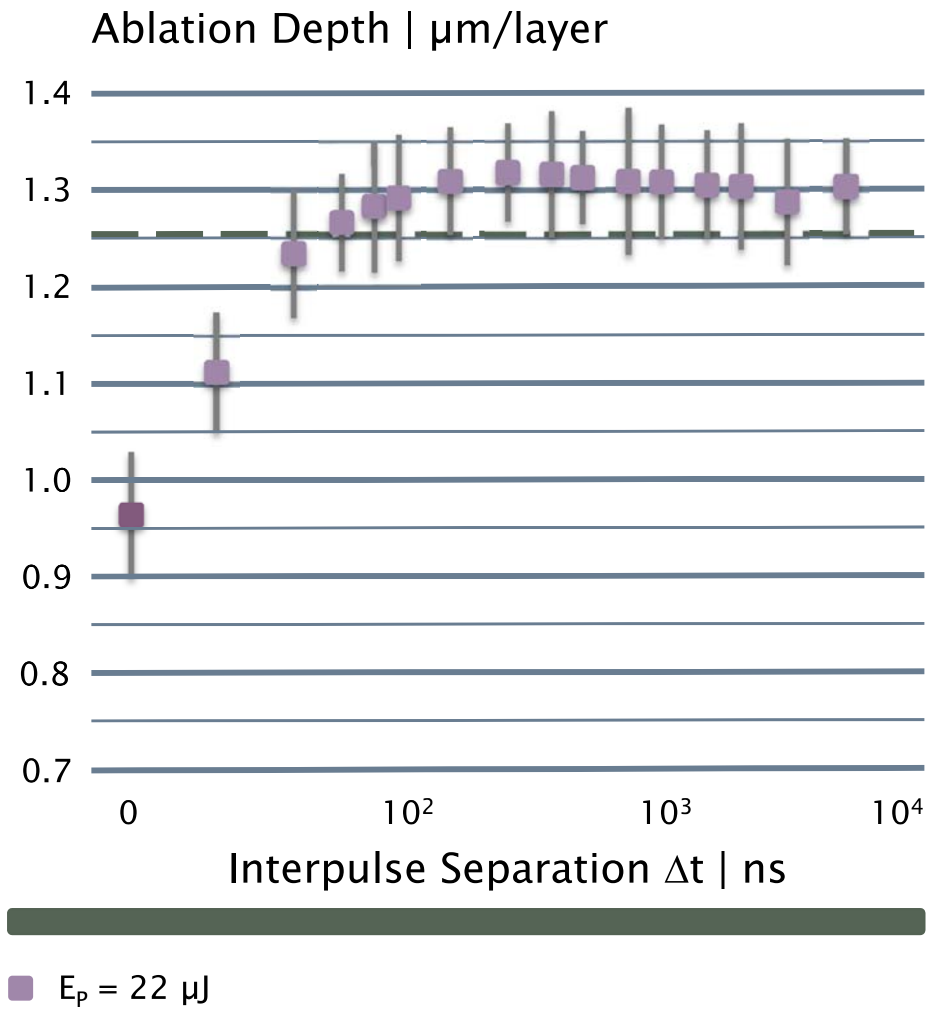


- reduction of repetition rate
- reduction of scan speed



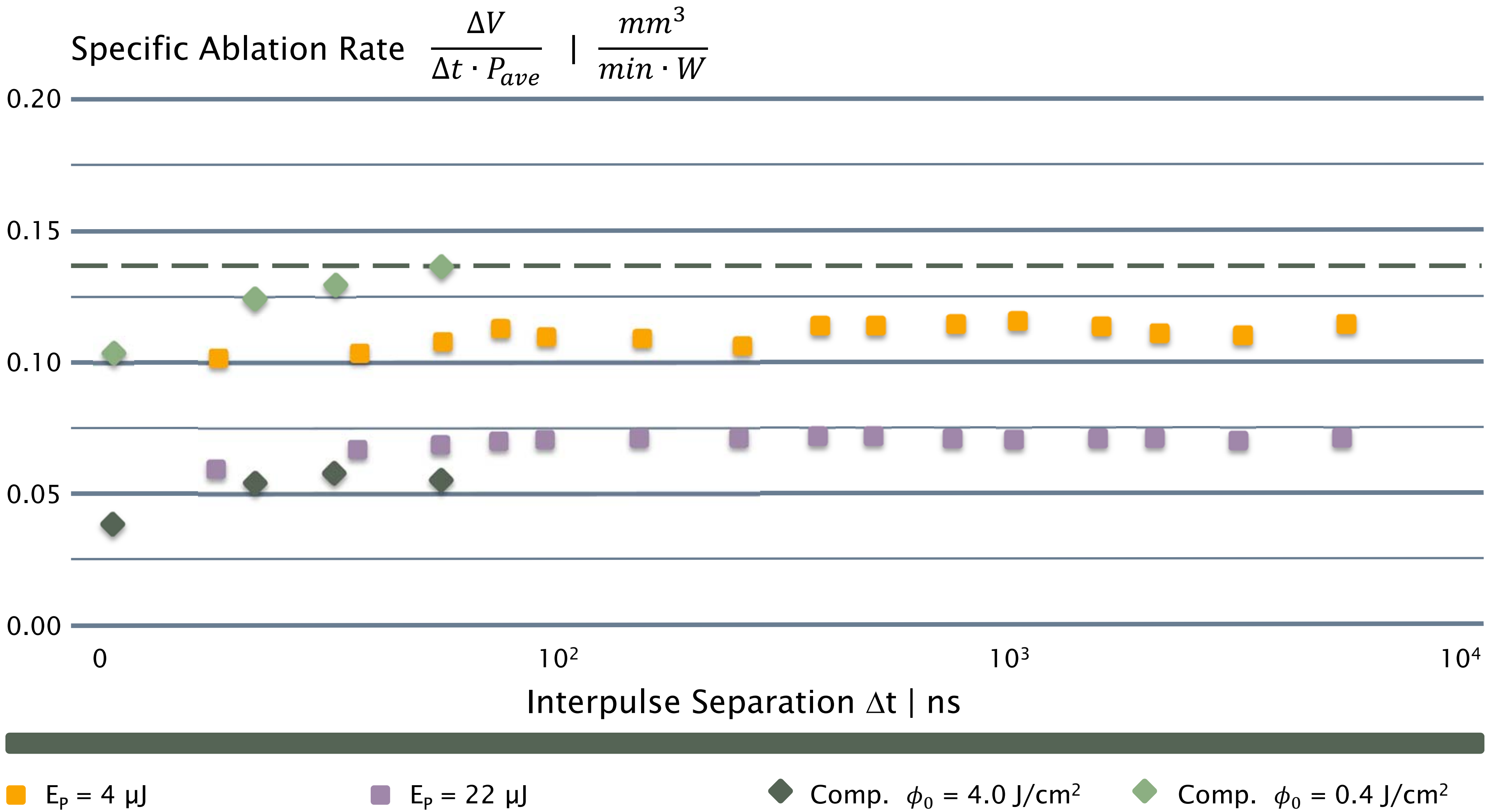
Applying Pulse Bursts





HARTMANN, C.; FEHR, T.; BRAJDIC , M.; GILLNER, A.: Investigation on Laser Micro Ablation of Steel Using Short and Ultrashort IR Multipulses; JLMN - Journal of Laser Micro/Nanoengineering Vol. 2, No. 1, 2007

Applying Pulse Bursts



HARTMANN, C.; FEHR, T.; BRAJDIC , M.; GILLNER, A.: Investigation on Laser Micro Ablation of Steel Using Short and Ultrashort IR Multipulses; JLMN - Journal of Laser Micro/Nanoengineering Vol. 2, No. 1, 2007

Applying Pulse Bursts

Typical Parameters of Today's Applications

w_0	36 µm	24 µm	12 µm	12 µm	29 µm
v_{scan}	3 m/s	3 m/s	3 m/s	30 m/s	60 m/s
f_{rep}	0.17 MHz	0.25 MHz	0.50 MHz	5.00 MHz	4.10 MHz
P_{ave}	1.5 W	1.0 W	0.5 W	5.0 W	25.0 W

Upscaling of Laser Power
Effects on Repetition Rate f_{rep} and Scanning Speed v_{scan}

w_0	36 µm	24 µm	12 µm	12 µm	29 µm
v_{scan}	110 m/s	160 m/s	325 m/s	650 m/s	270 m/s
f_{rep}	6 MHz	14 MHz	54 MHz	109 MHz	19 MHz
P_{ave}	50 W	50 W	50 W	100 W	100 W

Applying Pulse Bursts

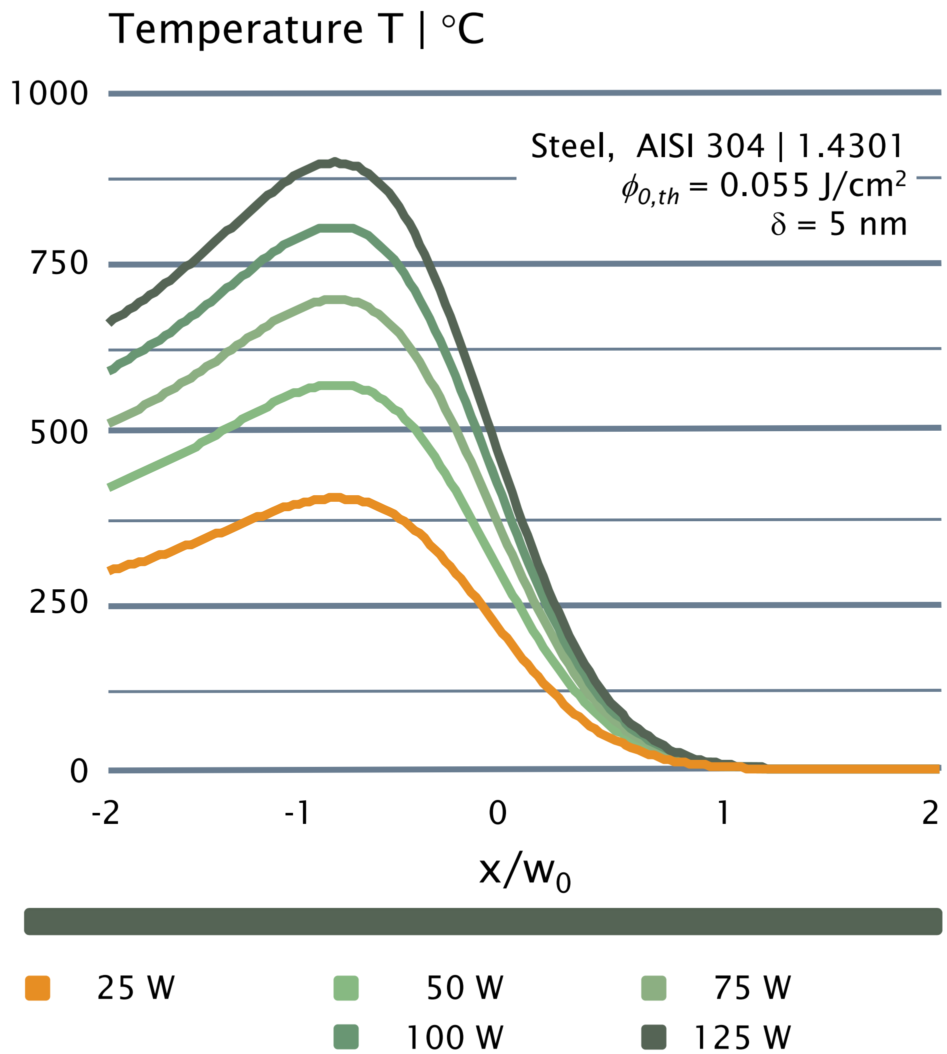
Upscaling Single Pulses

- working at optimum point

P_{ave}	f_{rep}	v_{scan}
25 W	4.1 MHz	60 m/s
50 W	8.3 MHz	120 m/s
75 W	12.4 MHz	180 m/s
100 W	16.6 MHz	240 m/s
125 W	20.5 MHz	300 m/s

Example Polygon Scanner

Beam Radius	w_0 =	29.0 µm
Pitch, $w_0/2$	p =	14.5 µm
Pulse Energy	E_P =	5.4 µJ



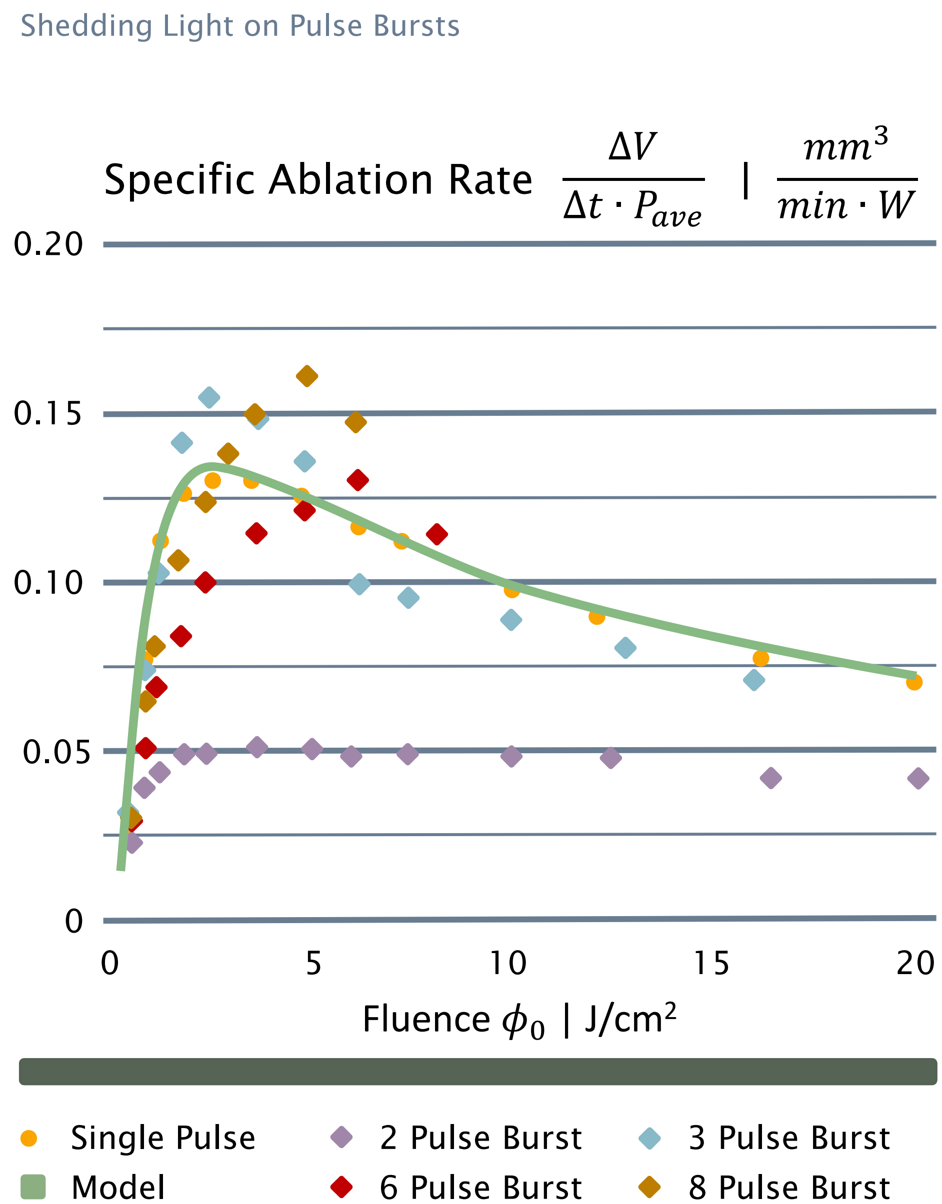
Applying Pulse Bursts

Copper

Applying Pulse Bursts

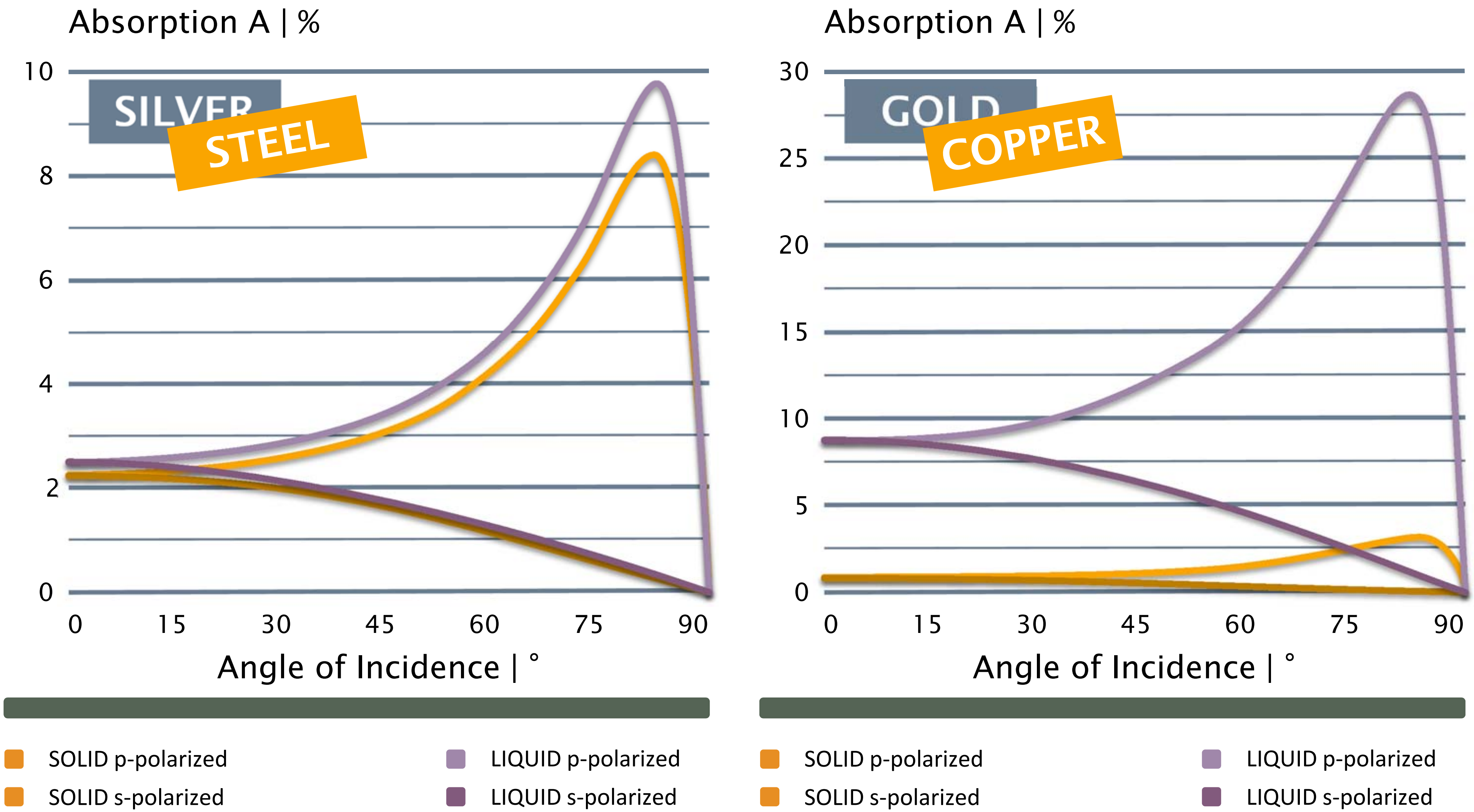
Comparison

- Copper DHP
- Repetition rate f_{rep} 200 kHz
- Interpulse Separation Δt 12 ns
- Pulse duration τ_H 10 ps



Applying Pulse Bursts

Shedding Light on Pulse Bursts



Summary

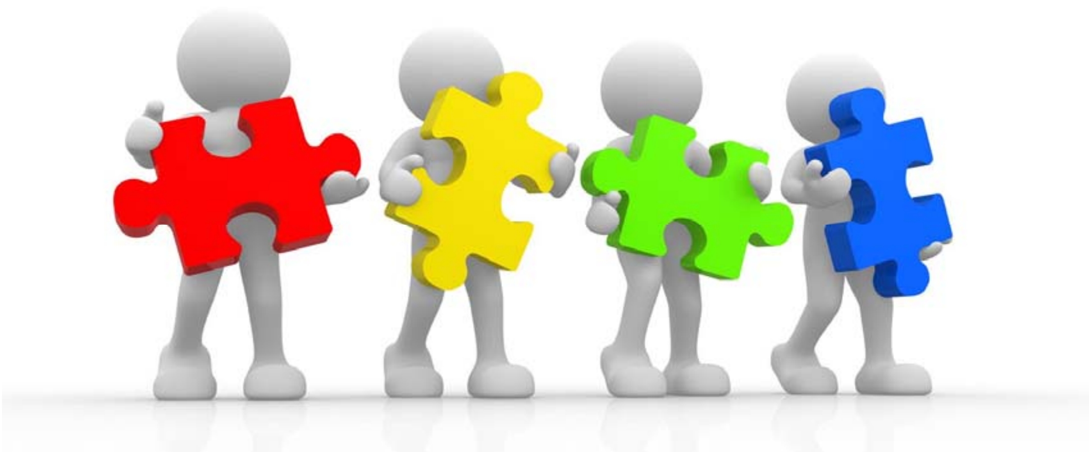
Summary

Steel

- Published higher ablation rates can be explained by reduction of pulse energy

Copper

- Increase of spec. ablation rate by means of three pulses burst
- Variation of pulse energy in the burst for every single pulse
- Variation of the interpulse spacing



Summary

Benefits of pulse burst

- Reduction of repetition rate @ constant average power
- Increase of average power @ constant repetition rate
- Increase of average power @ optimum pulse energy
- Increase of ablation rate (ablated volume per time)
- Higher specific ablation rate at high fluence
  (but never as high as at optimum point…)
- “Polishing” of surface

Thank you for your attention!