

# Discrete tunable laser for 3D imaging

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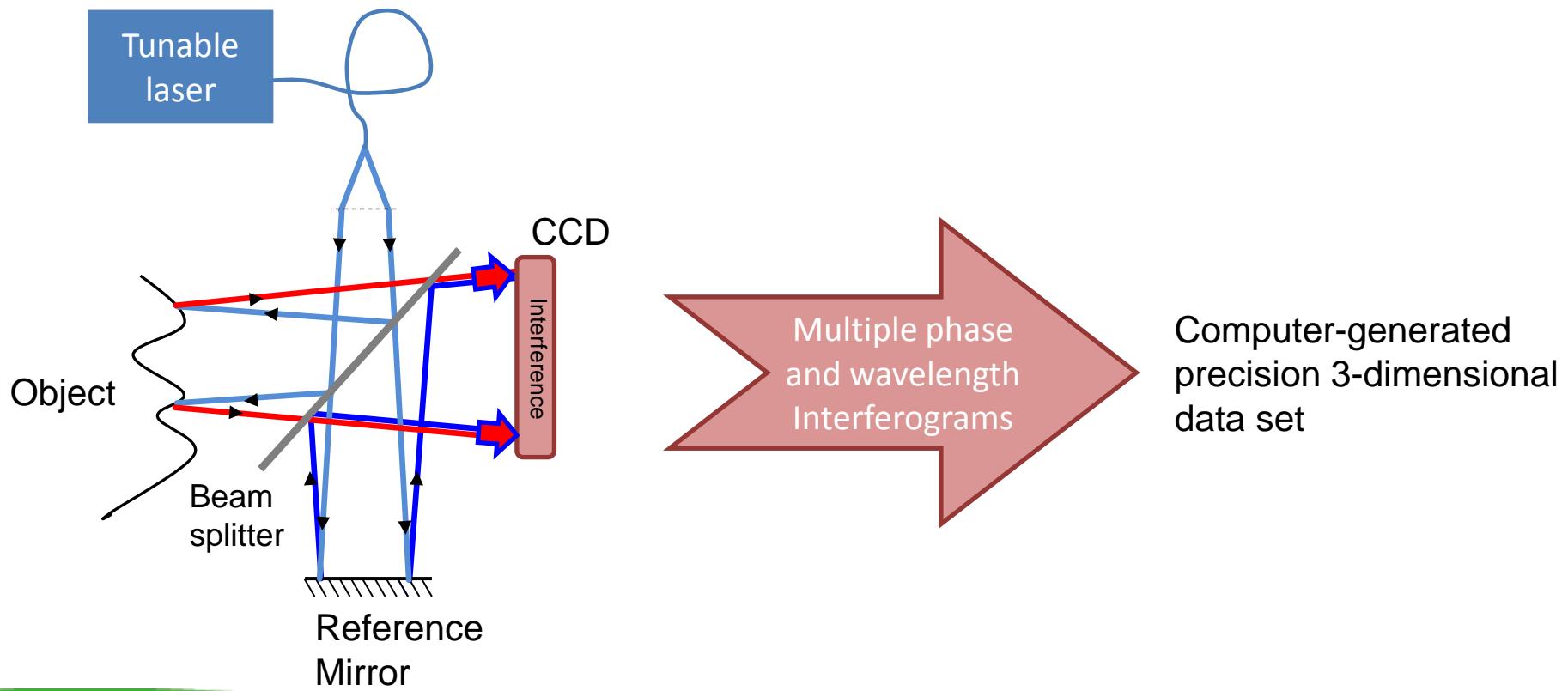
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## 3D Imaging / digital holography :

- Imaging object interferograms with multiple wavelengths and computer aided reconstruction of accurate depth information.



## **3D Imaging brings many benefits to industrial metrology:**

- sub  $\mu\text{m}$  depth resolution over centimeter range
- Non contact / non destructive
- High throughput
- Large area with sub-millimeter 2D resolution

## **Laser source requirements:**

- Wavelength stability and repeatability
- Narrow line width (long coherence length)
- Rapidly tunable
- Robust
- Compact /portable
- Low power consumption

- **External Cavity Laser (ECL)**

- AR coated broadband laser diode (750-790nm)
- Stable optical design

- **“Self-aligned” feature with folded cavity**

- Compact and easy to assemble

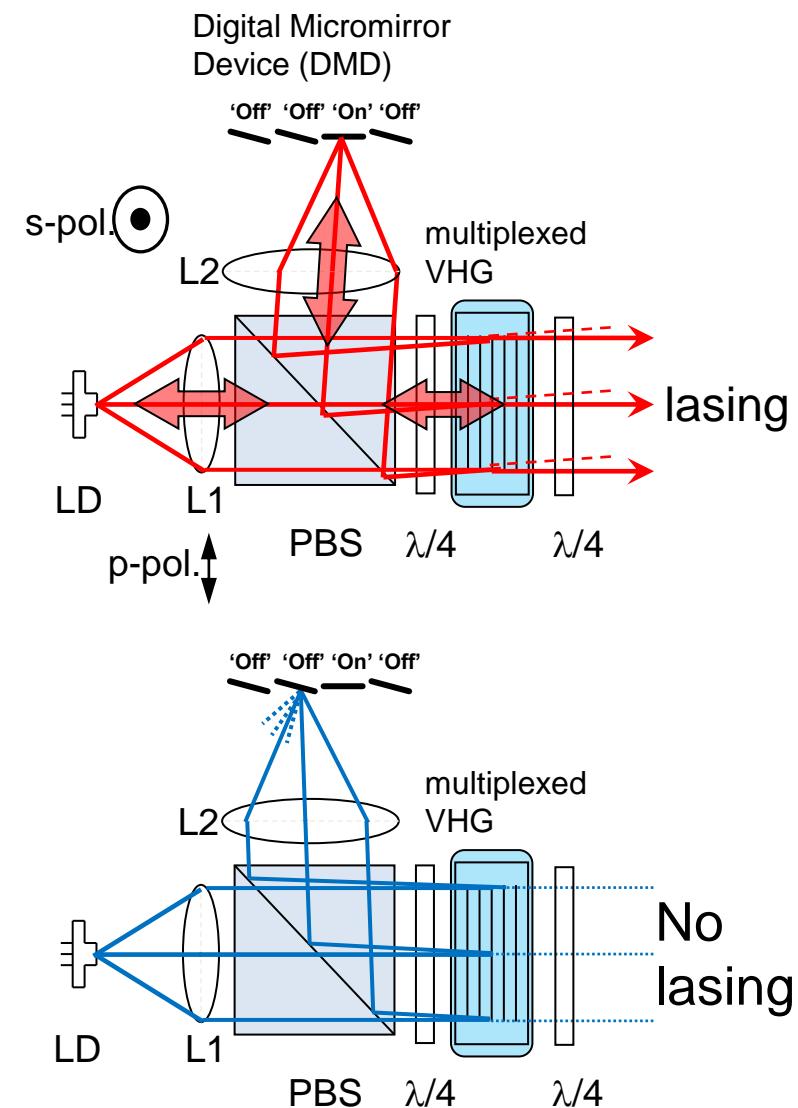
- **“Digital” tuning between  $\lambda$**

- Digital micromirror, not thermal or mechanical

- **Multiplexed Volume Holographic Grating (VHG) as wavelength selector**

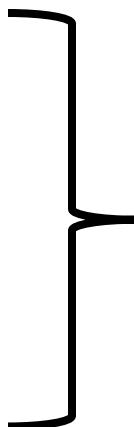
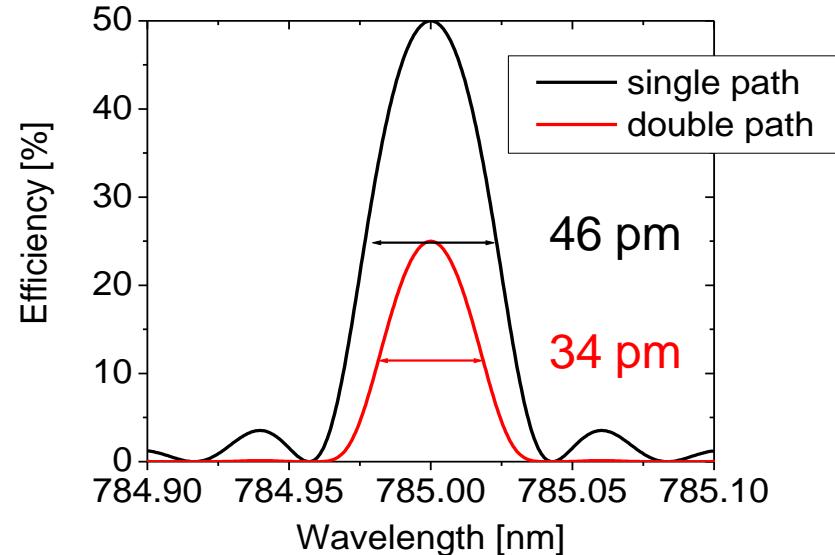
- Multiple, discrete wavelengths at any spacing (within diode bandwidth)
- 10 wavelengths demonstrated

- **Low power consumption**

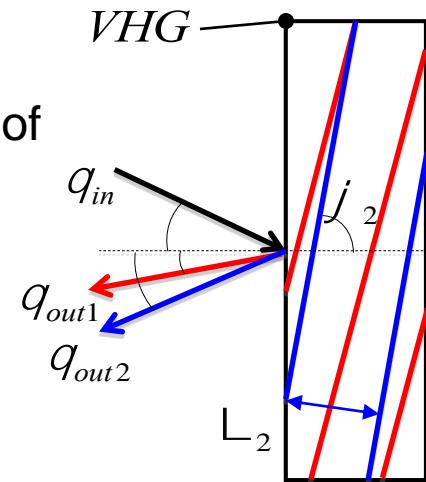


# Volume Holographic Gratings

- Periodic refractive index modulation inside a proprietary PTR glass substrate
  - “Solid State”
  - Unlimited lifetime
- Very narrow bandwidth
  - Highly selective for small diameter beams
- Non-dispersive
  - Discrete diffraction
- Multiplexing
  - Multiple discrete  $\lambda$  can be recorded at arbitrary diffraction angles

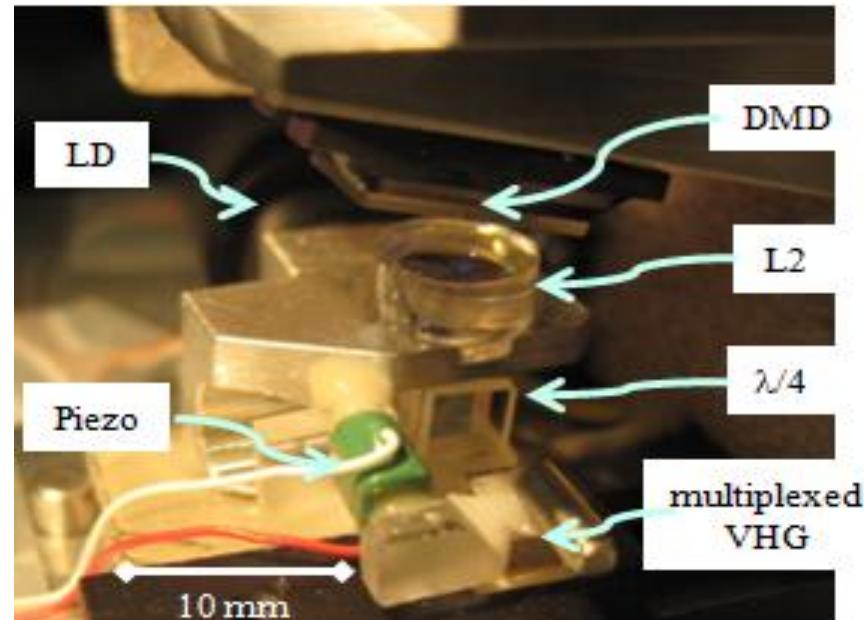


Allows design of discrete and arbitrary dispersion relation



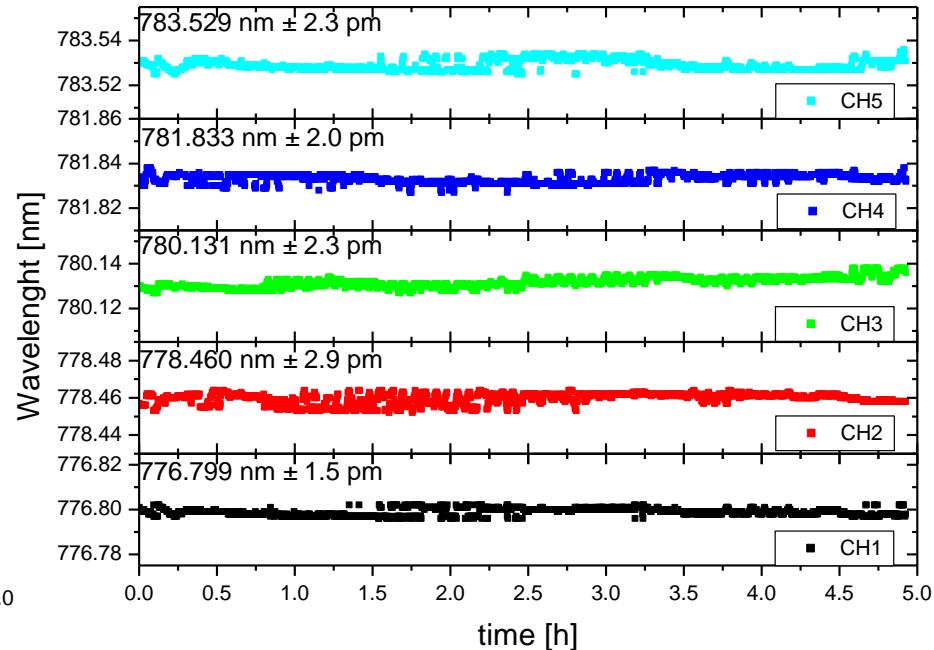
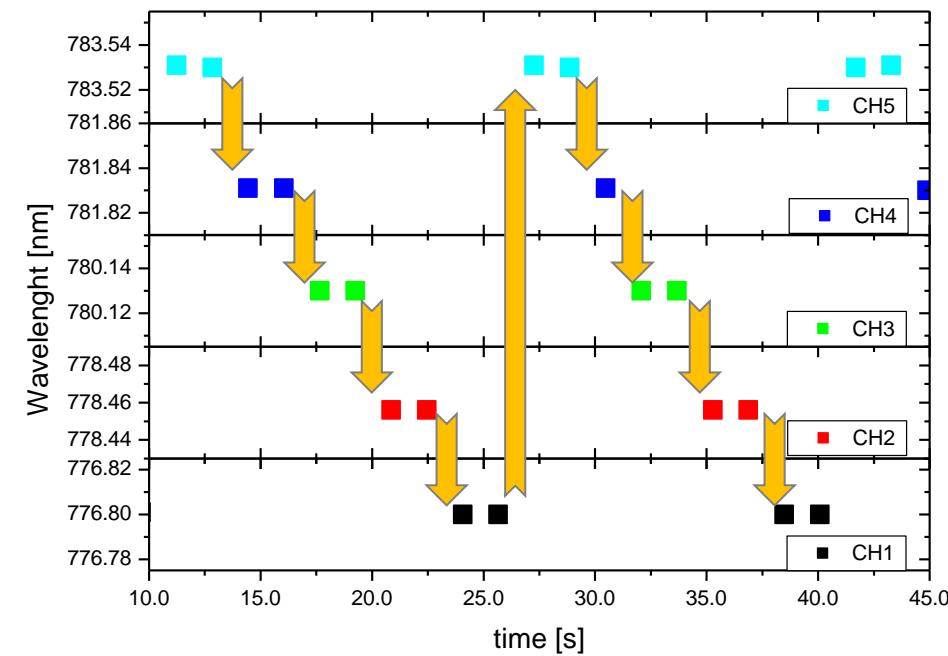
# 5 Channel Prototype

- Compact: 80 mm roundtrip cavity in only 10x10x10 mm<sup>3</sup> volume
  - Optical components bonded on TEC
  - Operated at ~ 10 C above RT
- > Low power, fast and precise temperature control
- 5 wavelengths selected to achieve ~ 7 nm (> 4 THz) tuning range
  - VHG slant angles selected according to DMD pitch (7.5  $\mu\text{m}$ ), mirror size and other optical constraints



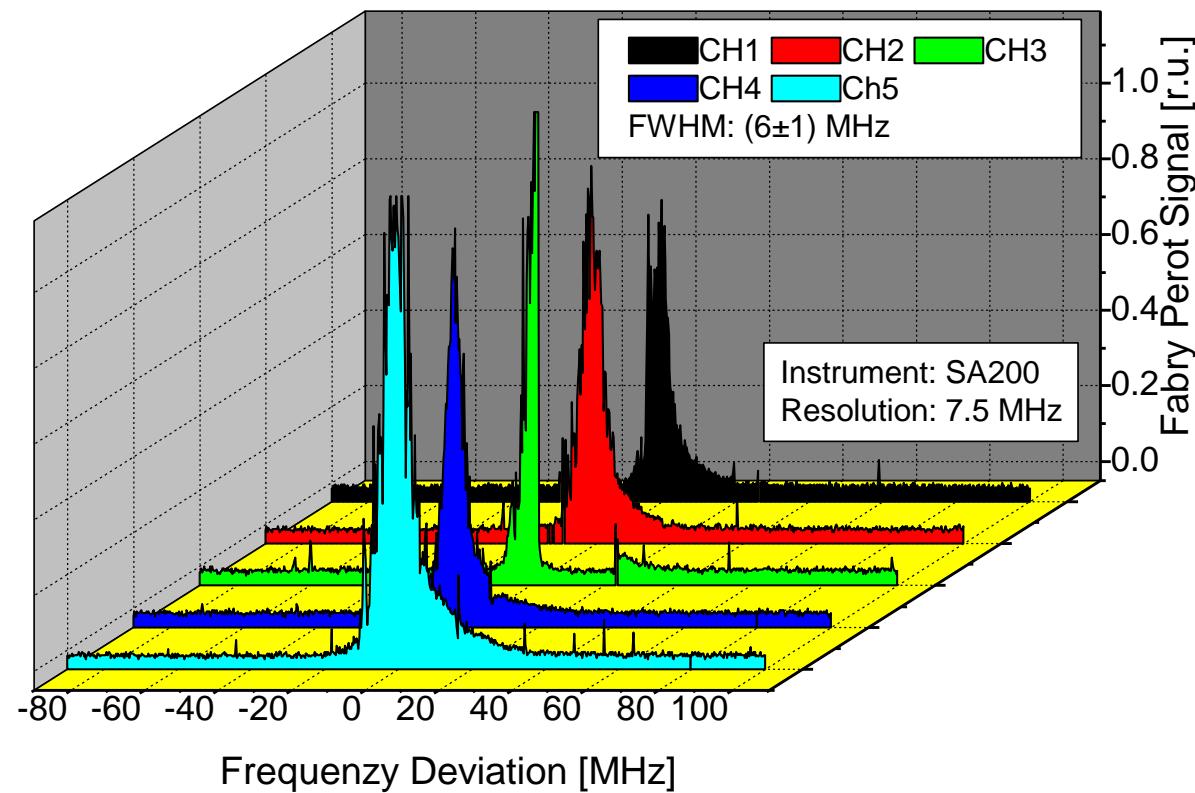
CH	Discrete Wavelength [nm]
1	783.53
2	781.83
3	780.13
4	778.46
5	776.80

# Wavelength Repeatability



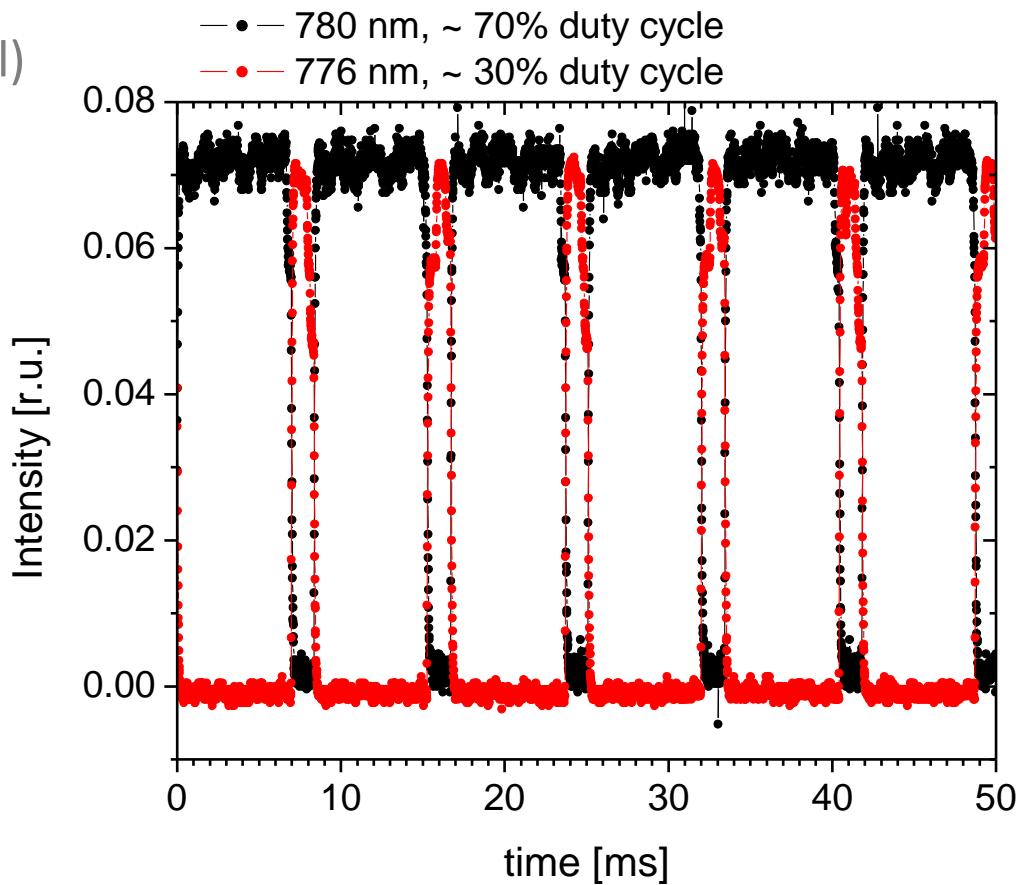
Better than +/-3 pm wavelength  
repeatability over 3600 cycles (5h)

- Consistent MHz line width for all 5 channels
- Instrument-limited measurement ( $\sim 7.5 \text{ MHz}$ )
- Estimated linewidth of  $< 1 \text{ MHz}$  ( $> 4 \text{ m}$ )

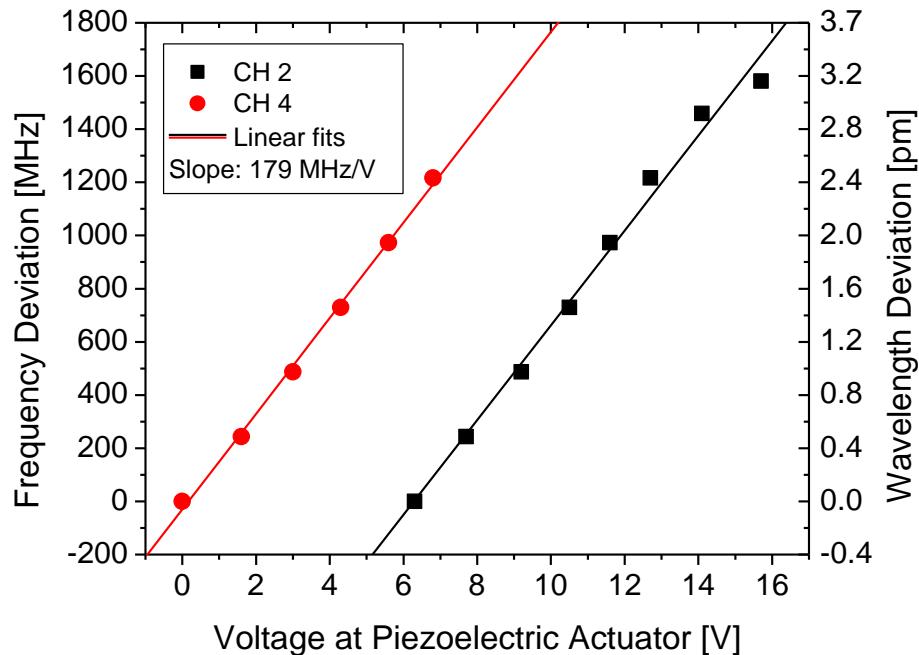
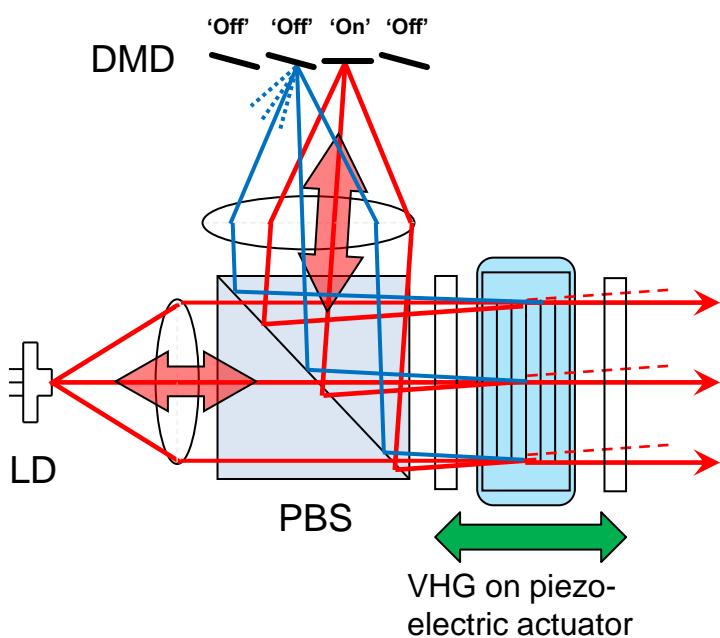


# Tuning Performance

- 50  $\mu$ s exponential rise and fall times ( $\sim 120 \mu$ s for 90/10 % level)
- No intermediate wavelength
- No settling required
- Highly repeatable:
  - Switching dynamic
  - Power levels
- Cycling speed (120 Hz) limited by DMD



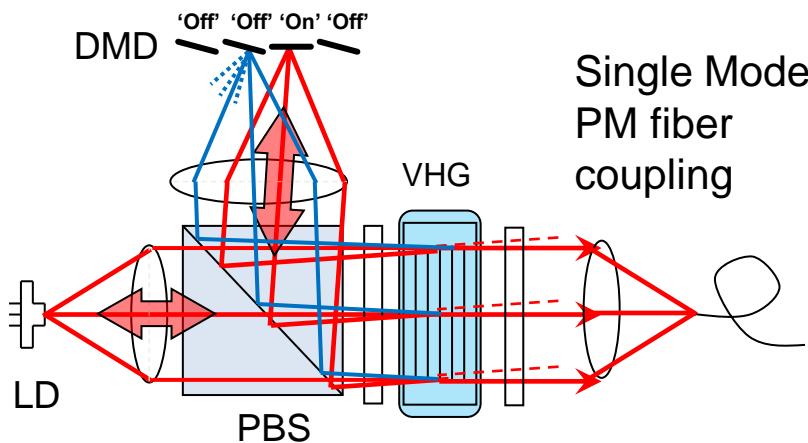
# Wavelength Fine Tuning



## Wavelength fine tuning:

- Easily integrated
- 4 pm continuous tuning range
- Enables active locking

- Free space power demonstrated up to 40 mW at max current
  - ~< 0.5 W overall electrical power consumption
- consistent, balanced operation > 20 mW for all 5 channels at nominal operating current (110mA)



- 50 – 55% PM fiber coupling efficiency for all 5 channels
- Independent of wavelength or power

- New laser source introduced for Digital Holography
  - Discretely tunable, external cavity laser design
  - Multiplexed VHG, folded “self-aligning” cavity
  - Compact low power consumption
- 5 channel prototype demonstrated
  - Fast and repeatable tuning ( $\pm 3 \text{ pm}$ ,  $120 \mu\text{s}$  rise time,  $120 \text{ Hz}$ )
  - Narrow line width ( $\sim 1 \text{ MHz}$ )
  - Up to  $40 \text{ mW}$  optical power ( $\sim <0.5 \text{ W}$  consumption)
  - 55% coupling efficiency into PM fiber independent of wavelength or power
  - Other applications: THz Wave generation, Raman spectroscopy



# Acknowledgements

National Science Foundation:  
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## Ondax Product Line

The image displays a variety of optical components and a detailed 3D model of an optical system. At the top, there is a horizontal row of seven smaller images showing different parts: a gold-colored lens element, a black rectangular laser module, a cylindrical component with a wire, a blue rectangular filter or housing, a gold-colored grating, a black circular disk, and a silver rectangular block. Below this row is a large, intricate 3D rendering of a complex optical device, possibly a laser cavity or a beam splitter, composed of numerous metallic and glass-like components. At the bottom of the image, there is a dark blue banner with white text identifying specific product categories.

Volume Holographic Gratings  
Wavelength Stabilized Lasers

Pulse Compression Filters  
Narrowband Notch Filters

ASE Suppression Filters  
VHG Wavelength Combiners

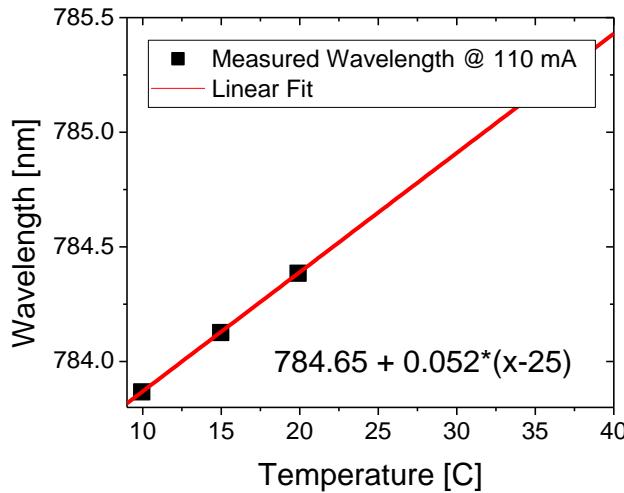


# ONDAx

# Coherent THz Photomixing

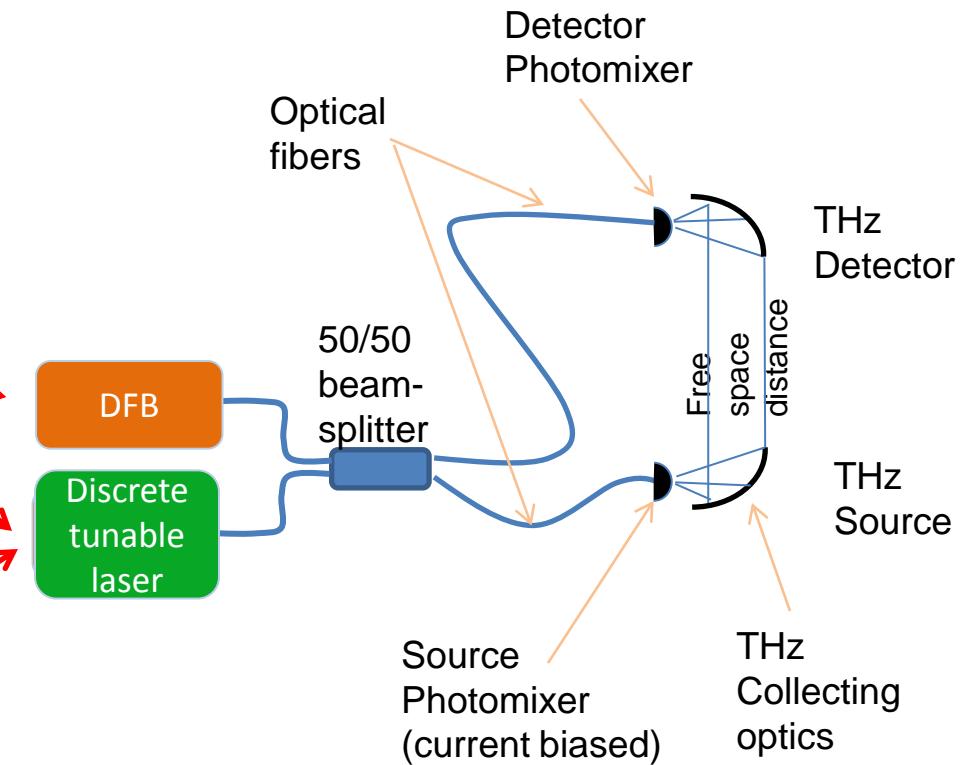
Backup

## DFB laser (EMCORE, PB1316-783)



## Discrete tunable laser

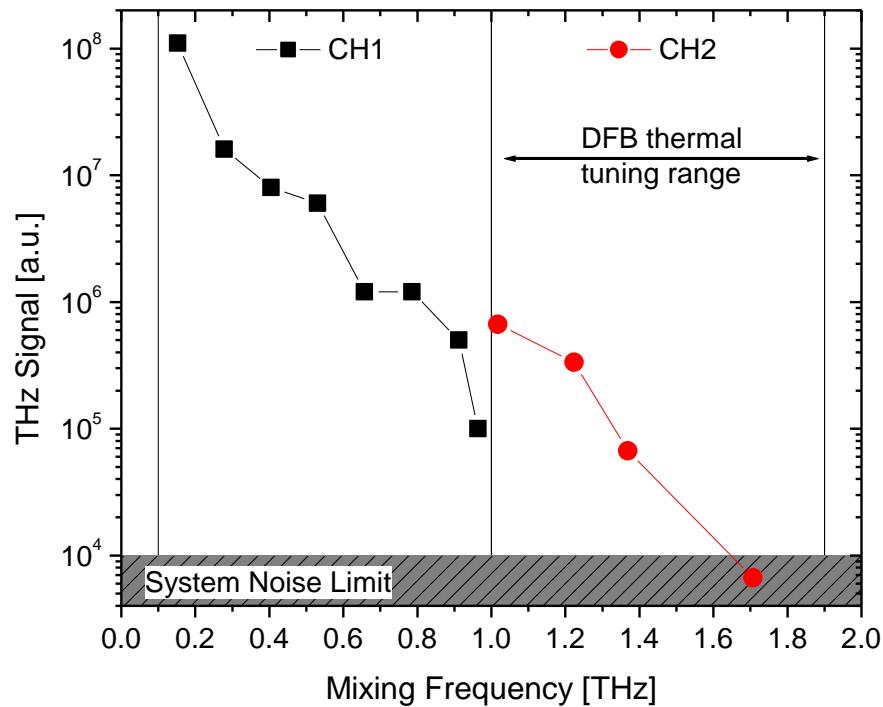
CH	Discrete Wavelength [nm]	Mixing Frequency [THz]	
		Minimum	Maximum
1	783.53	0.15	1.04
2	781.83	0.99	1.87
3	780.13	1.82	2.7
4	778.46	2.64	3.53
5	776.8	3.47	4.35



Terahertz Spectrometer  
Emcore, PB2700



- Clear THz signal for 2 channels up to 1.5 THz
- Signal strength in line with estimates based on optical power
  - Power-limitations and noise floor compromised broader range measurements



- 50  $\mu$ s exponential rise and fall times (185  $\mu$ s for 99/1 % level)
- No intermediate wavelength
- No settling required
- Speed limited by DMD

