NAVOLCHI

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Technische Universiteit **Eindhoven** University of Technology

Where innovation starts

Milestones and Deliverables

MS40	Individual plasmonic devices characterization, testing and evaluation	WP6

- Contents of D6.1 will be used (Report on characterization results of all plasmonic devices).
- An e-mail will follow requesting additional input (if any)

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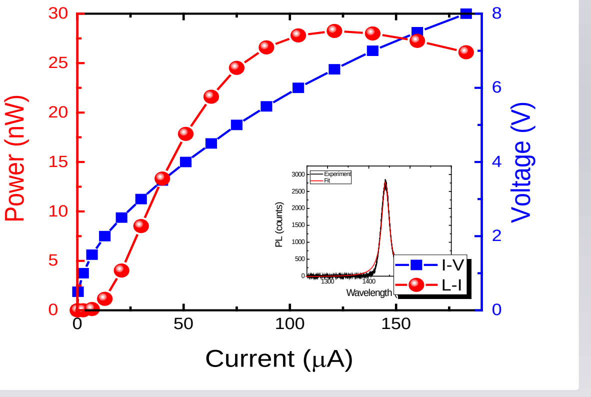
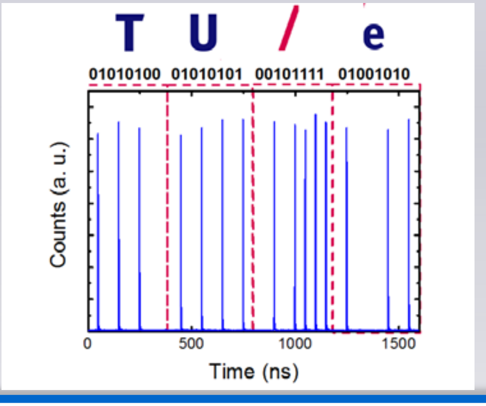
Outline

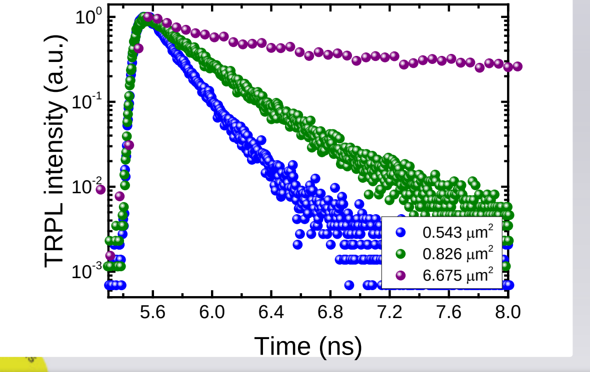
1. Electro-optical characterization



2. Direct electrical modulation of nanoLEDs



3. Optically pumped time-resolved measurements of InGaAs nanopillars



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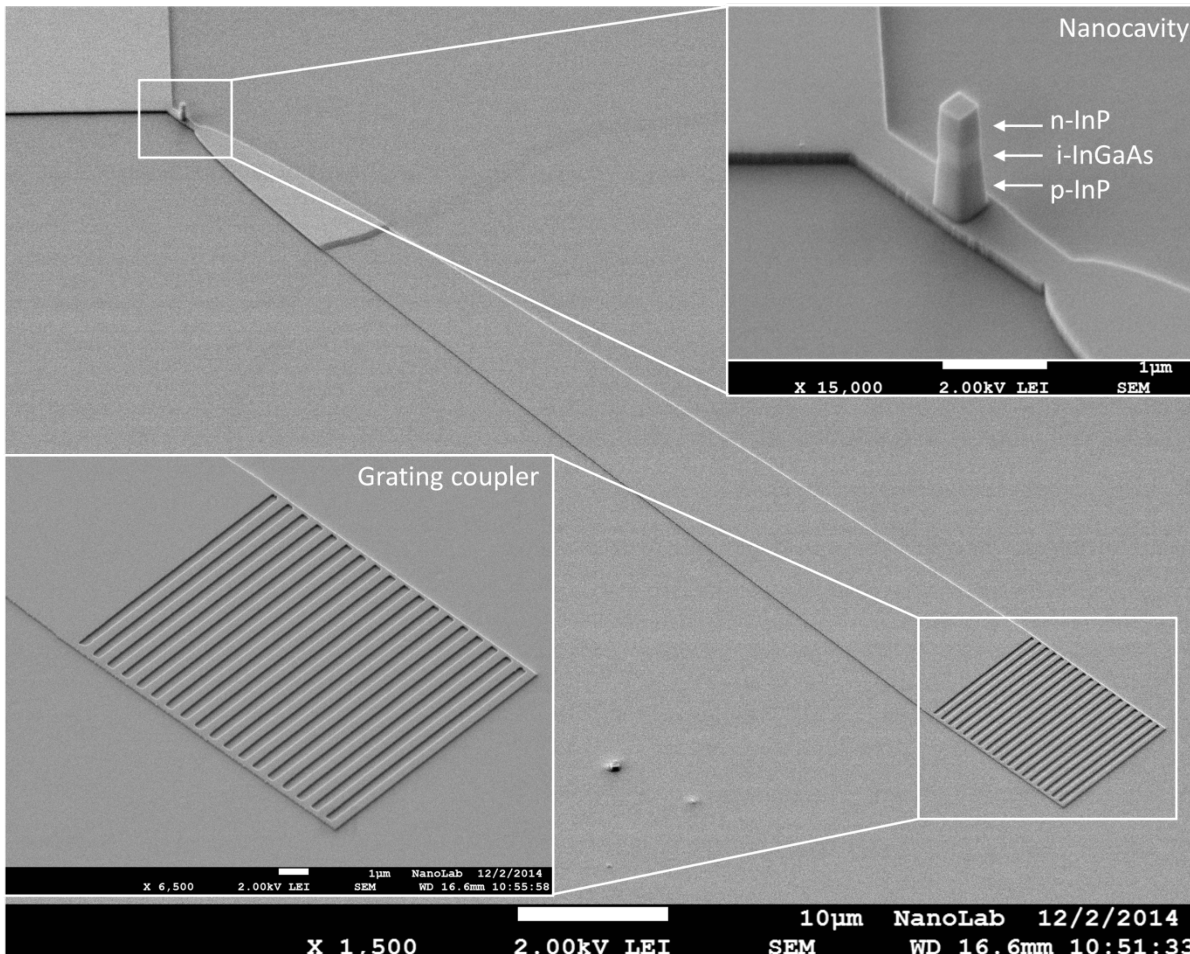
Integrated nanoLED for photonic circuits

- **The metal-cavity nanoLED was fabricated in a III-V layer stack bonded to a silicon wafer**



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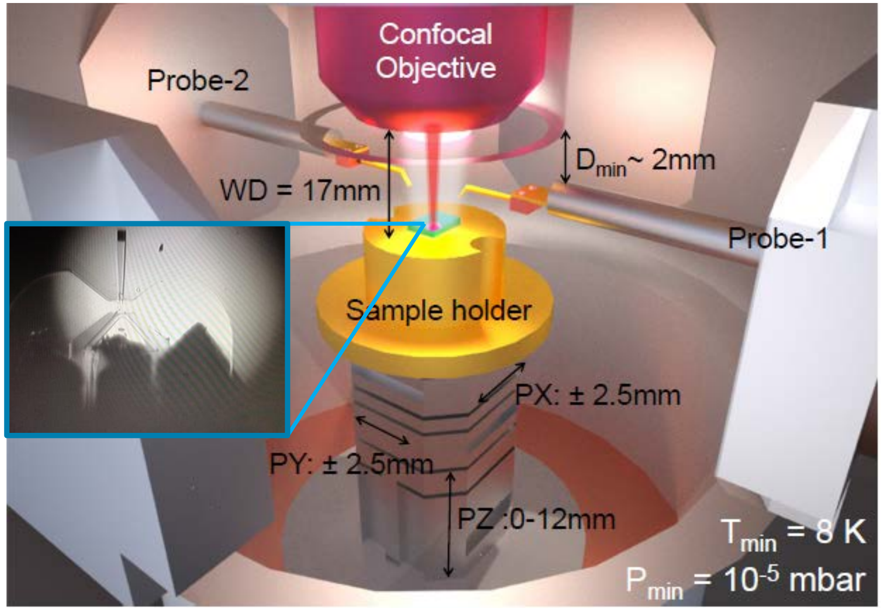
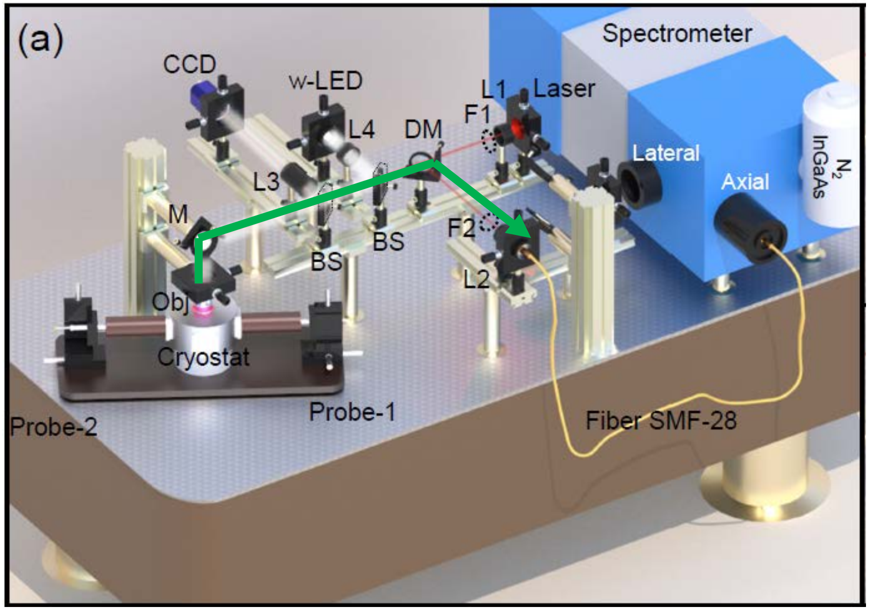
Experimental characterization setup

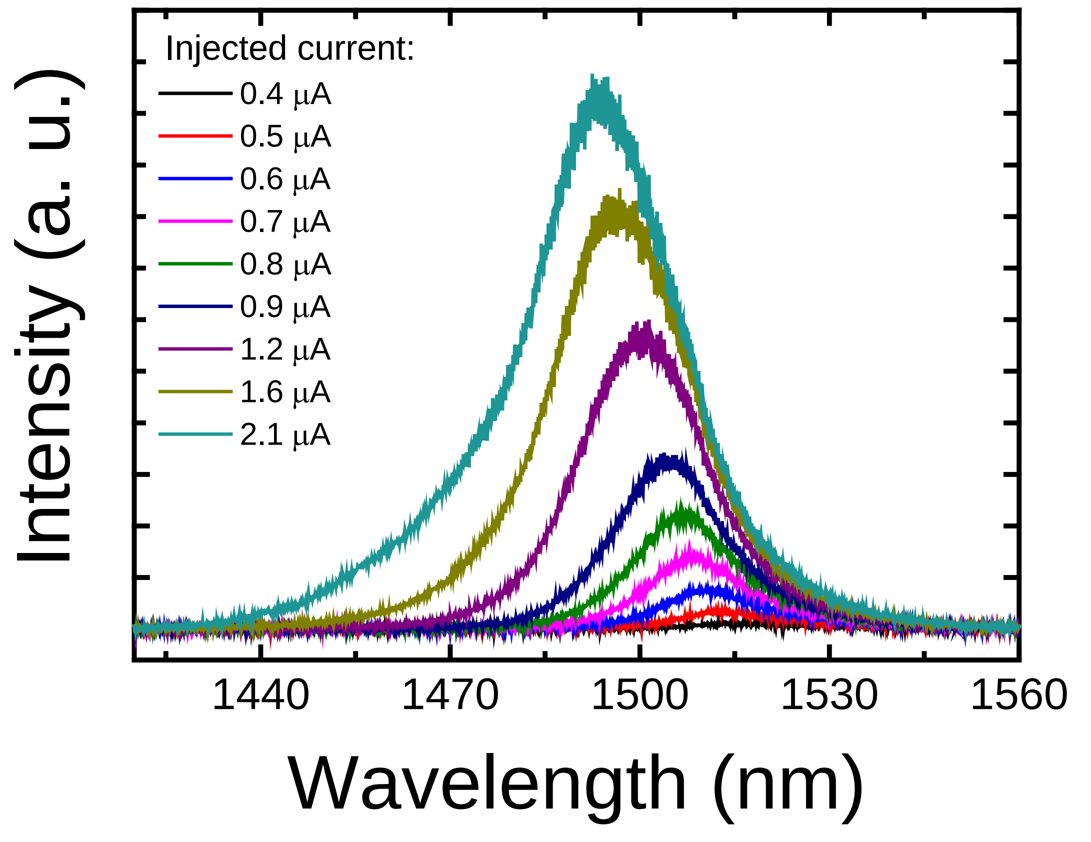
- **Electro-luminescence setup with a cryogenic chamber**
- **Temperatures: RT, 150K, 75K, 9K**
- **Collection spot ~2 µm (grating coupler ~10x12 µm^2)**
- **Maximum collection angle: 23°**





F. Pagliano, PhD thesis, 2014.

Emission spectra



- **Operation at telecommunications wavelengths (~1.5 um);**
- **FWHM ranging from 20 nm to 50 nm at low injection currents;**
- **Wavelength blueshift (carrier induced change in the refractive index)**

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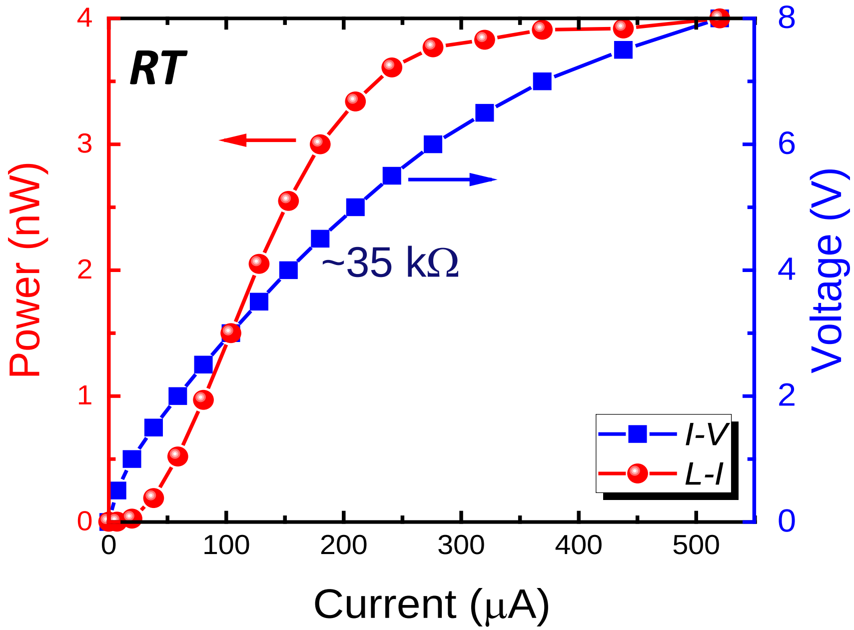
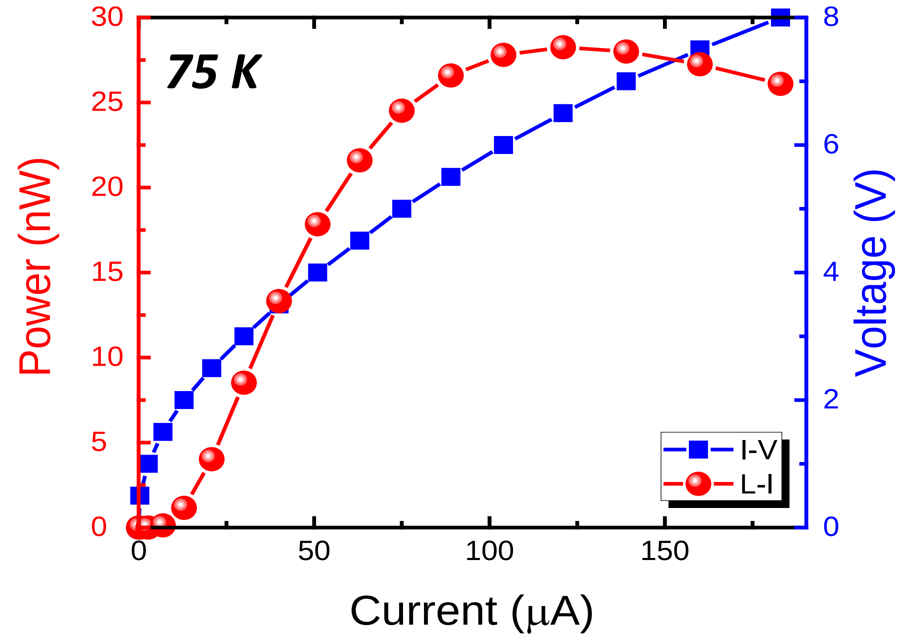
L-I-V characteristics



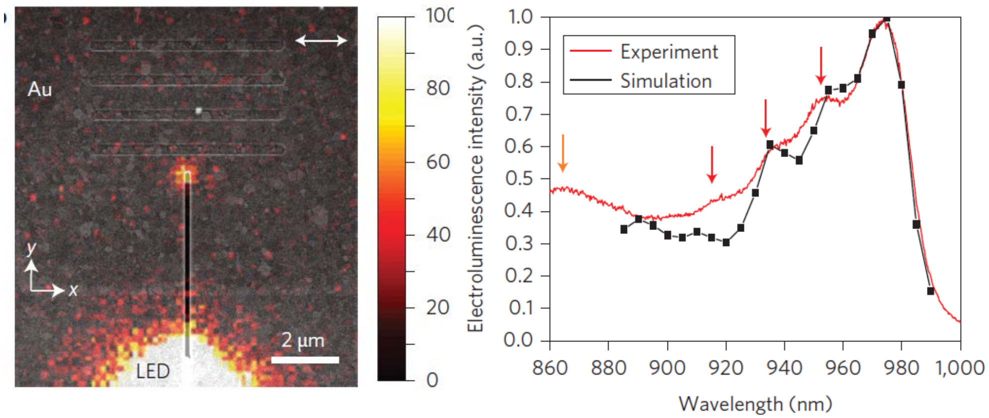


- Smooth turn-on voltage:
  → Leakage current?
- Max. power: **4 nW**

- Shifted turn-on voltage due to low temperature
- Max. power: **28 nW**
- **Efficiencies ~10^{-3} W/A**

Nano-sources in the literature

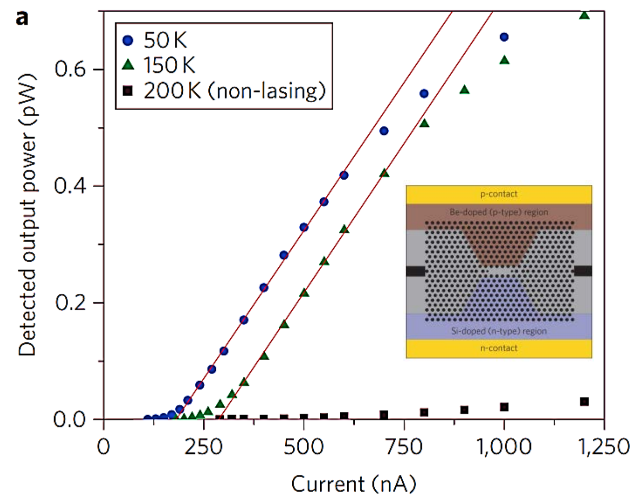
Powers in arbitrary units



Plasmonic light-emitting diode

(Kevin C. Y. Huang et al., Nature Photonics 8, 2014)

Powers below 1 pW!



Electrically pumped photonic crystals

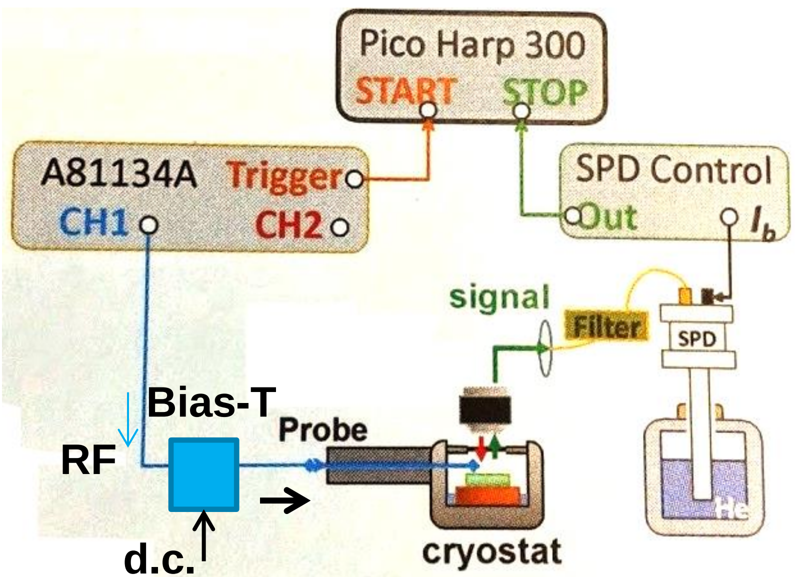
(Bryan Ellis et al., Nature Photonics 5, 2011)

Reported efficiencies in the literature spanning from 10^{-5} to 10^{-7}

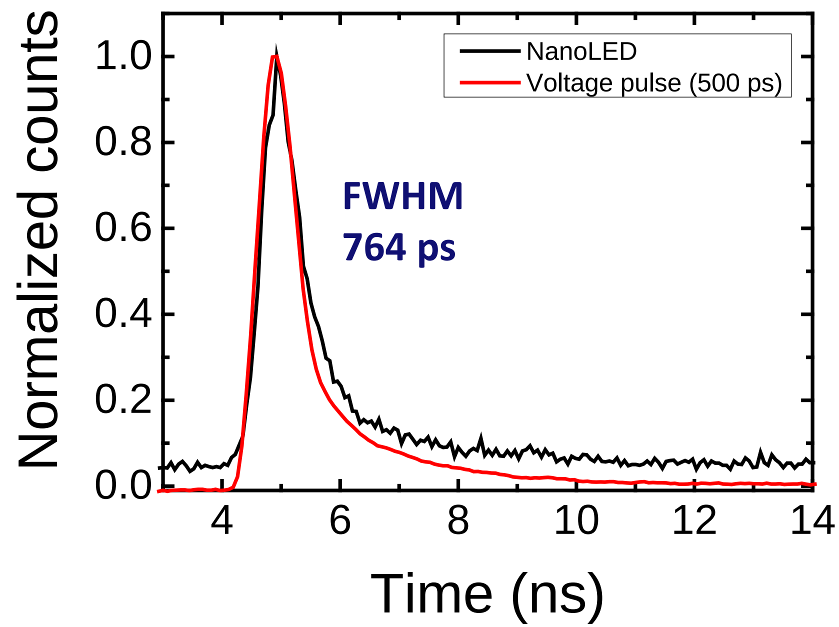
We achieved 10s of nW at 10s uW bias levels ⇨ 10^{-3}

Direct electrical modulation of nanoLED

Time resolved experimental setup



Room-temperature
(bias current of 28 μA)



- **Sub-nanosecond FWHM (~0.5 ns minimum)**
- **Potential to operate at Gb/s speeds.**

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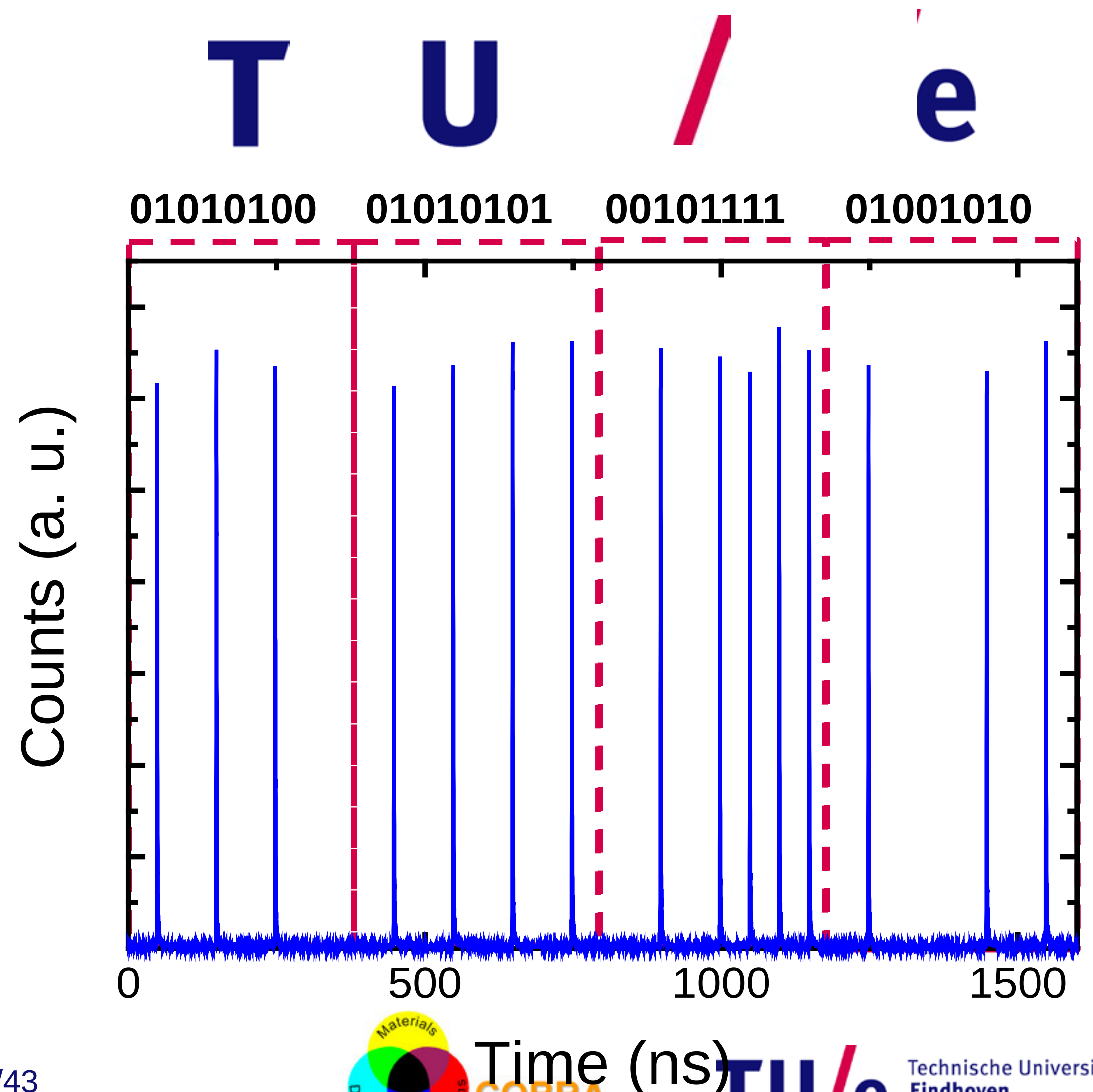
''Encoding'' a message in a nanoLED

Message sent in a nanoLED:

Hundreds of MB/s, potentially Gb's

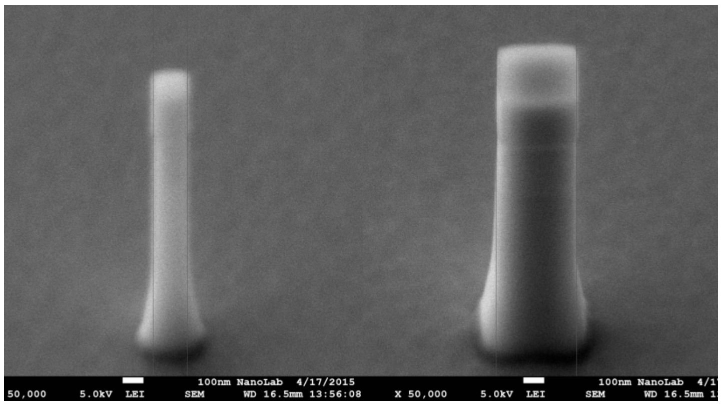
→ Ongoing

This is a statistical measurement!



Photoluminescence in InGaAs nanopillars

- **SEM pictures of the smallest pillars**



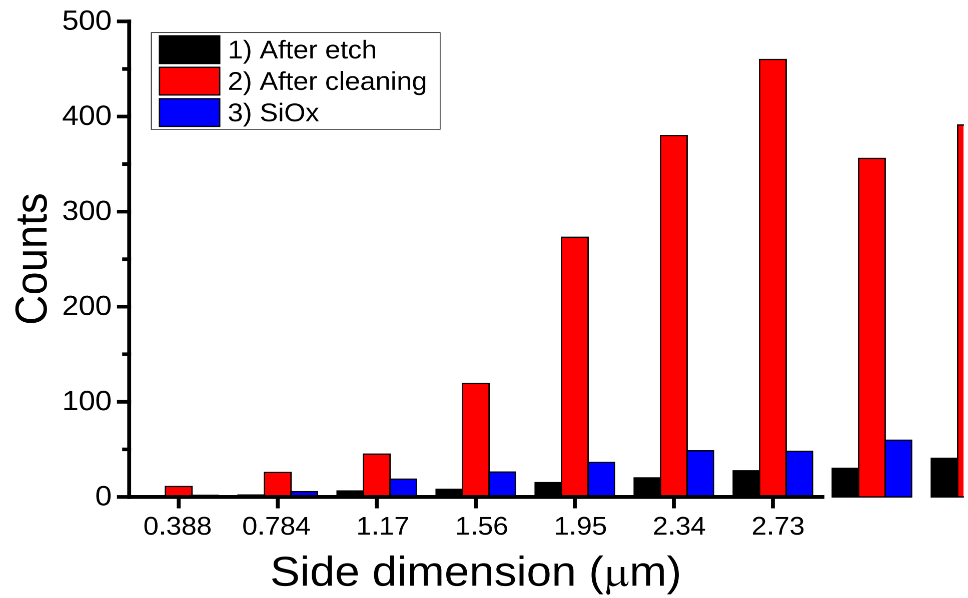
- **Layer stack**

Layer	Thickness
InP	350
InGaAs	350
InP	1000
InP	Substrate

- **Steps**

1) **Etching+O2**
2) **Cleaning**
3) **SiOx deposition @ 300℃ + annealing**

- **PL summary results**



- **The deposition of SiOx at high temperature is strongly affecting the optical properties of the pillars**

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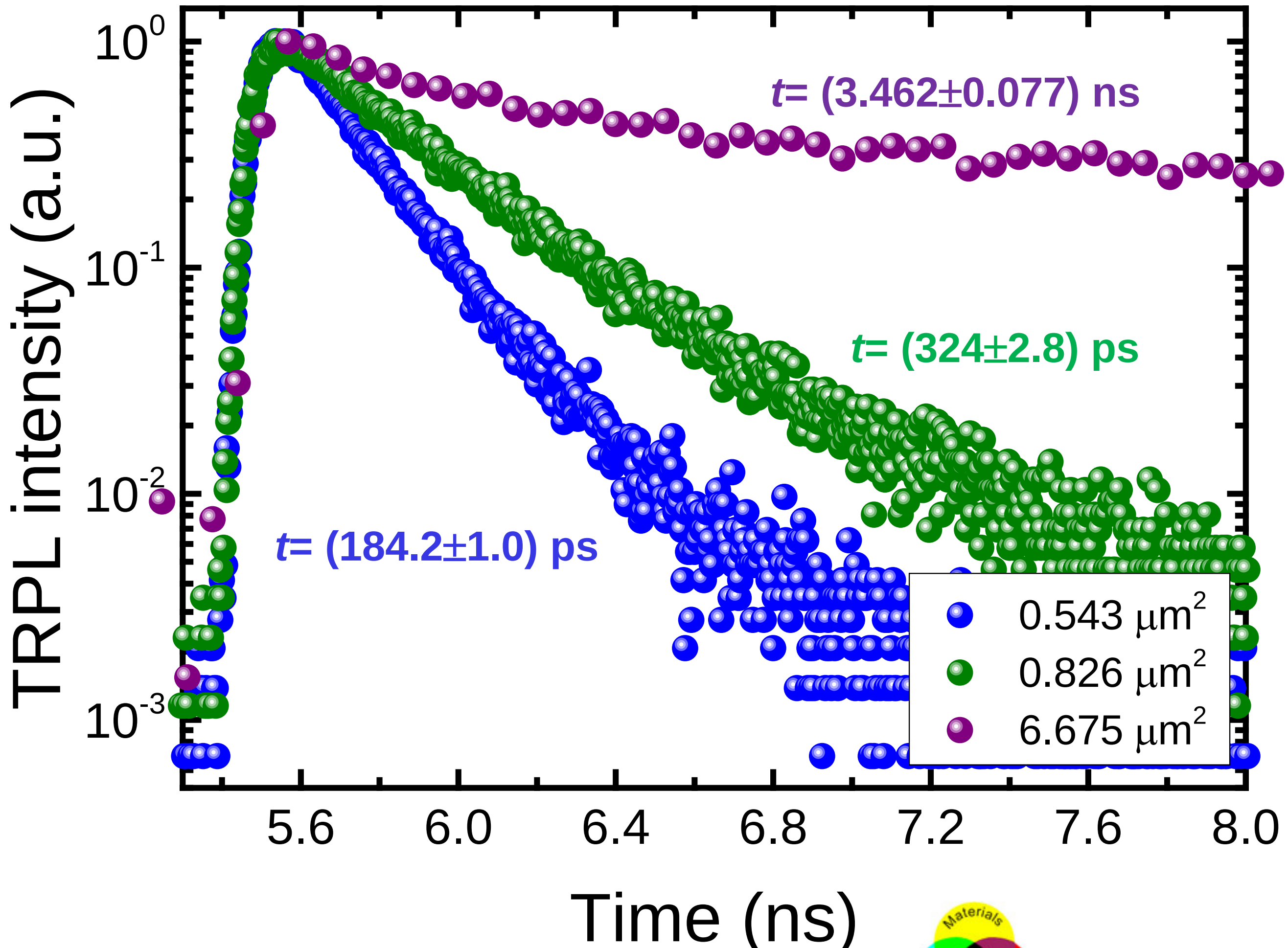
Decay time vs. pillar size



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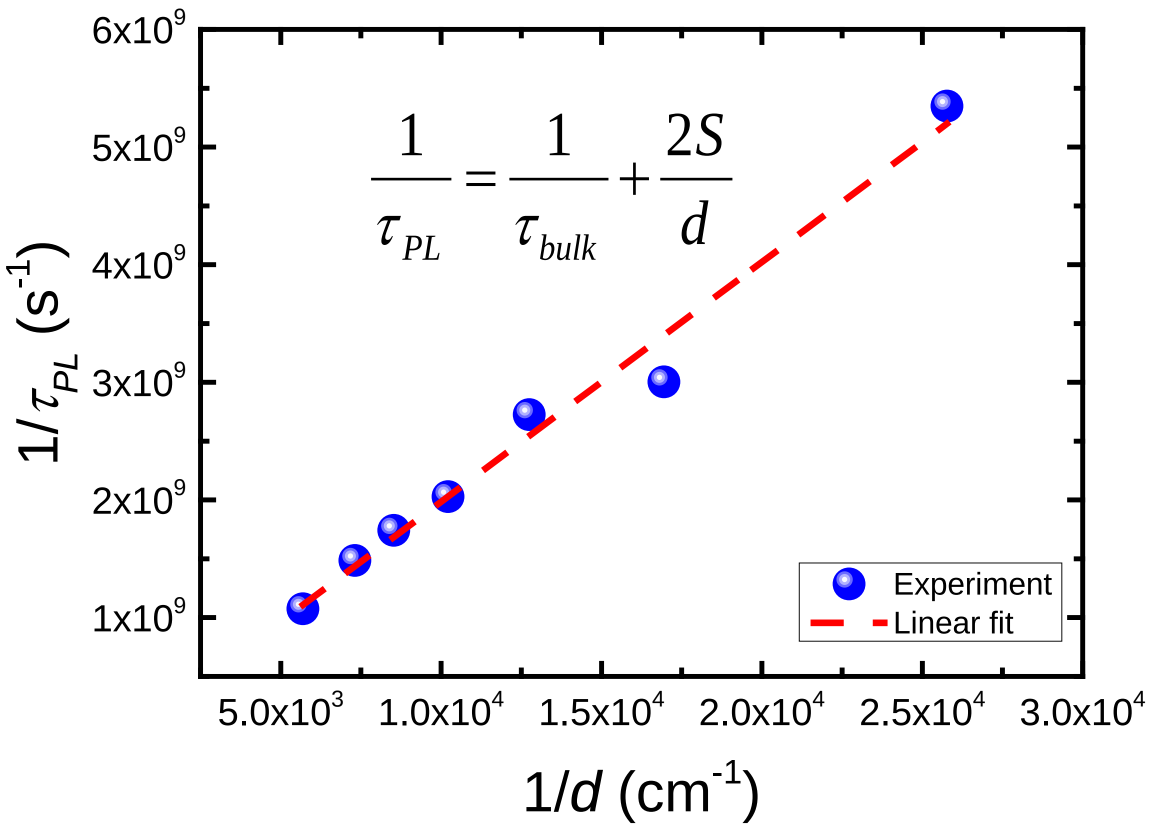
Surface recombination and bulk lifetime



$$\frac{1}{\tau_{PL}} = \frac{1}{\tau_{bulk}} + \frac{2S}{d}$$

Extracted parameters:

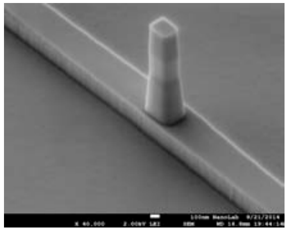
$S \sim 1\times10^5$ **cm s^{-1}**

$\tau_{bulk} \sim 4.8$ **ns**

- **<u>Large surface recombination</u> indicating strong non-radiative losses;**
- **The presence of <u>a fast non-radiative recombination</u> gives rise to the possibility of a high-speed operation at room temperature.**

Conclusion

- **Demonstration of an electrically pumped metal cavity nanoLED coupled to a InP-waveguide on silicon.**



- **Possibility of a fast, efficient, nanoscale source for on-chip communication:**

✓ **Operation at telecommunication wavelengths (~1.5 um);**

✓ **Measured output powers of tens of nW and efficiencies up to ~10^{-3} W/A;**

✓ **Sub-nanosecond direct electrical modulation.**