



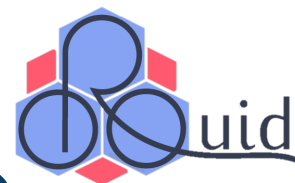
# INTEGRATED ORGANIC MOLECULES For QUANTUM TECHNOLOGIES

YIQIS 2020

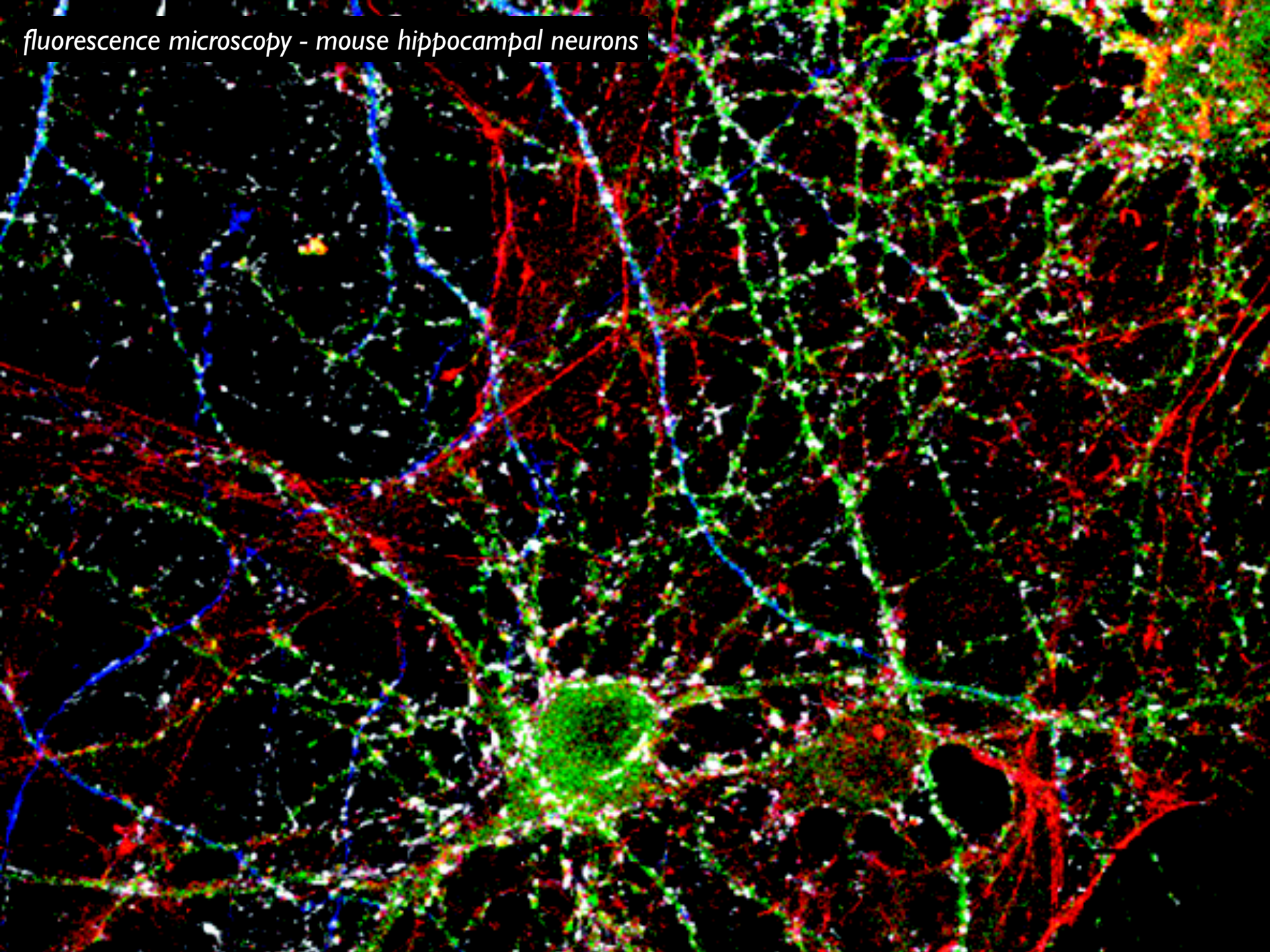
Maja Colautti

Lab of Quantum Nanophotonics

Costanza Toninelli (PI)

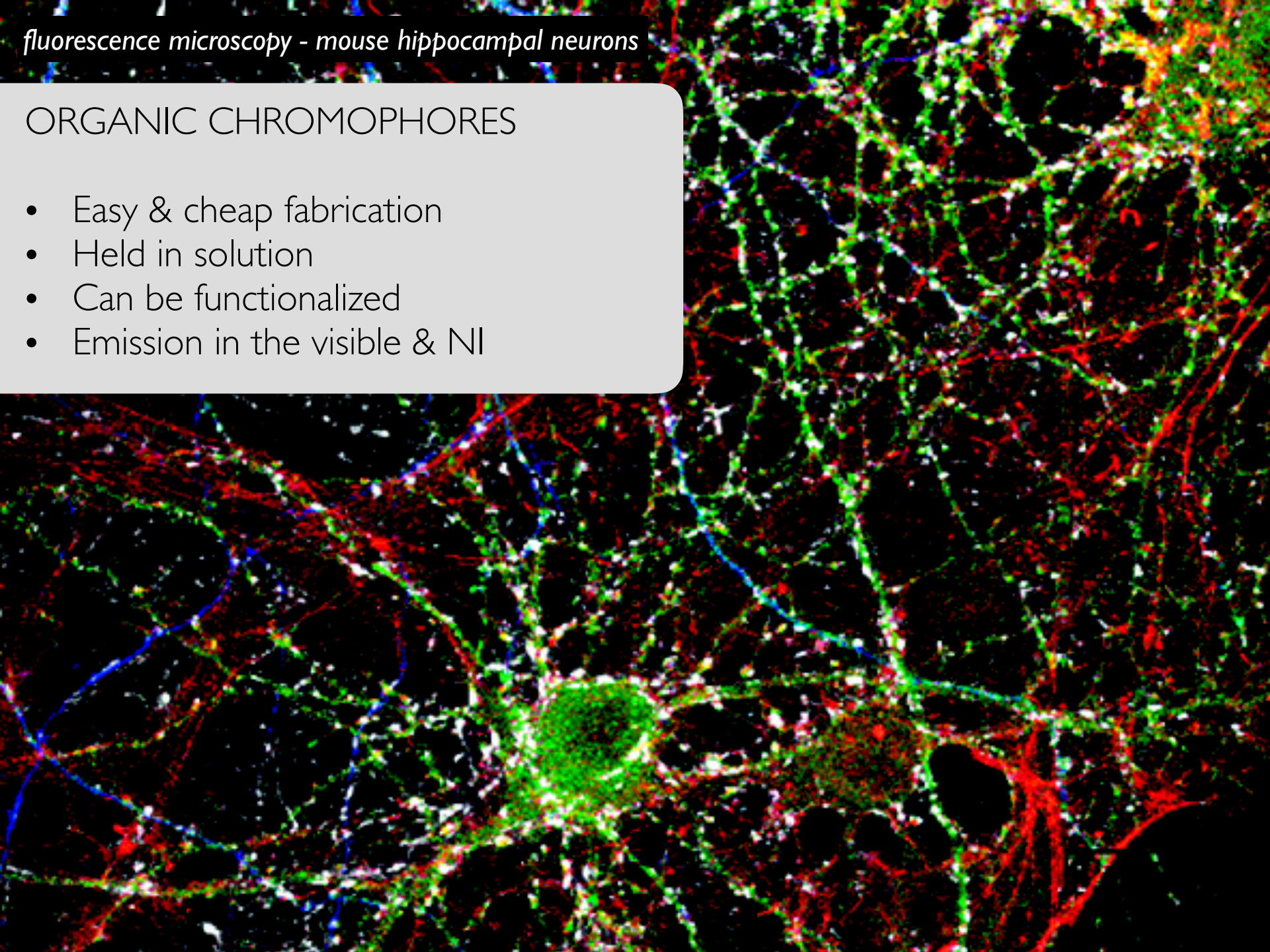


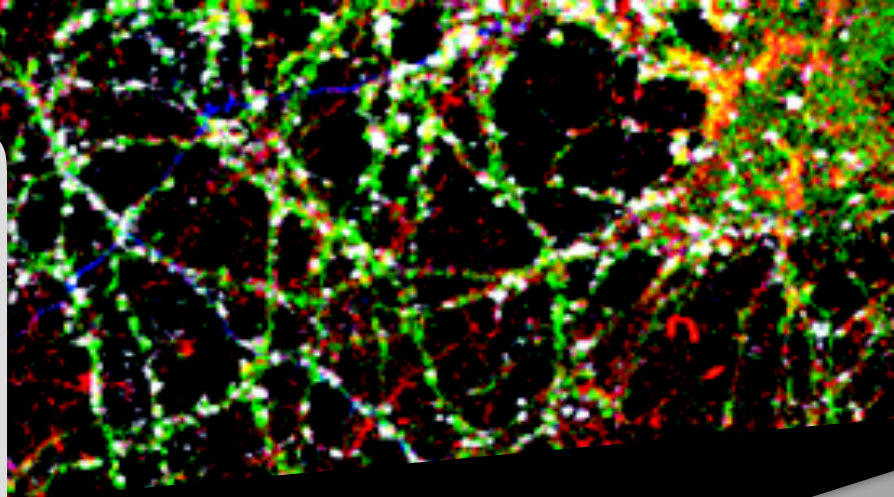
*fluorescence microscopy - mouse hippocampal neurons*



## ORGANIC CHROMOPHORES

- Easy & cheap fabrication
- Held in solution
- Can be functionalized
- Emission in the visible & NI



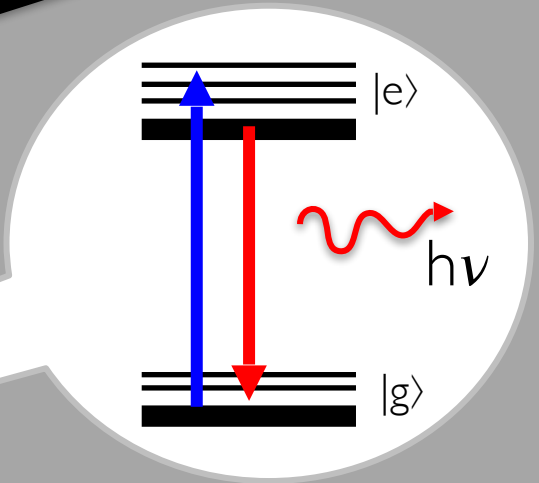
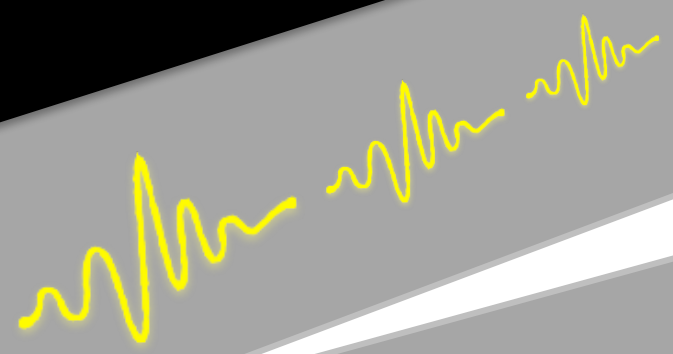
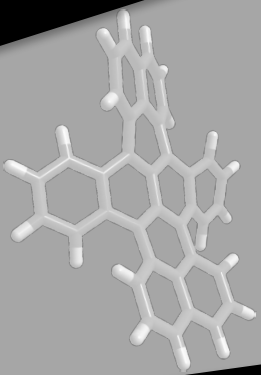


## ORGANIC CHROMOPHORES

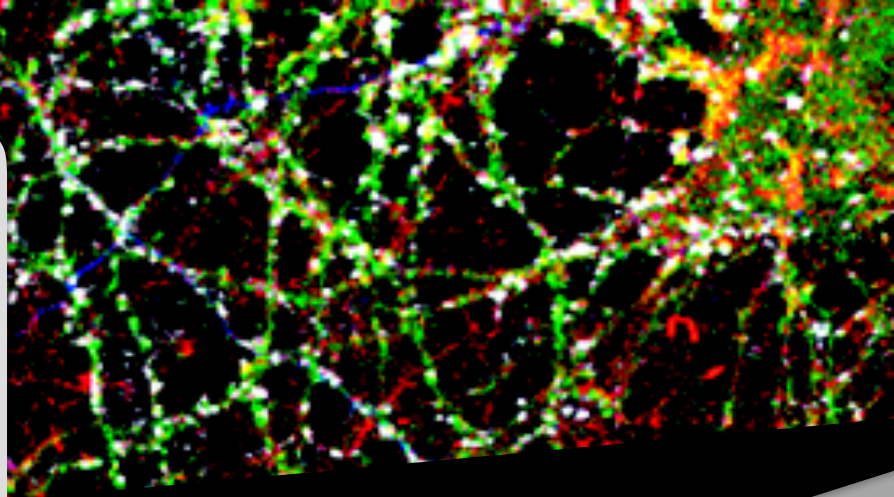
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...in **QUANTUM Optics**

- Q. Communication & Computing
- Q. Sensing
- Q. Radiometry



fluorescence microscopy - mouse hippocampal neurons

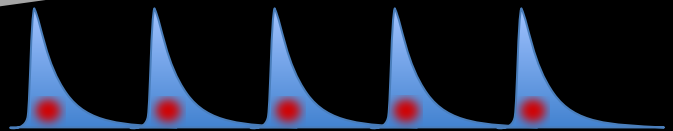
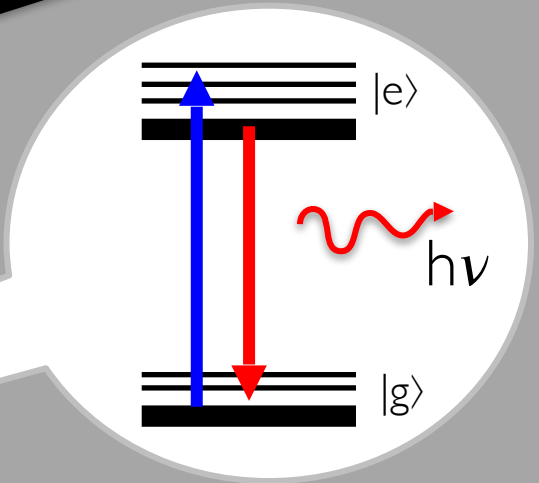
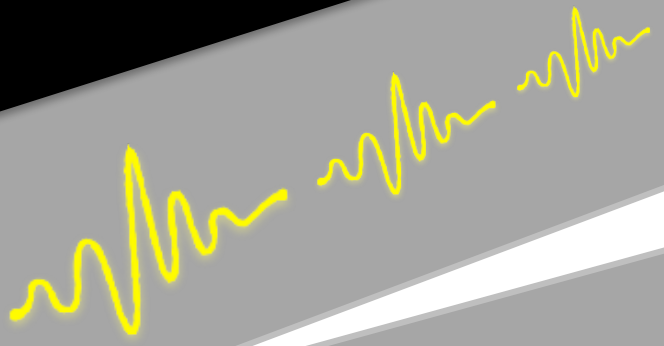
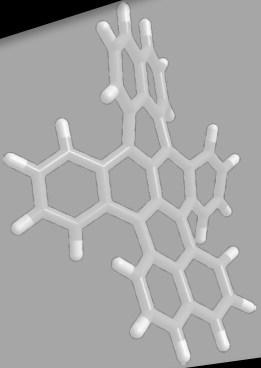


## ORGANIC CHROMOPHORES

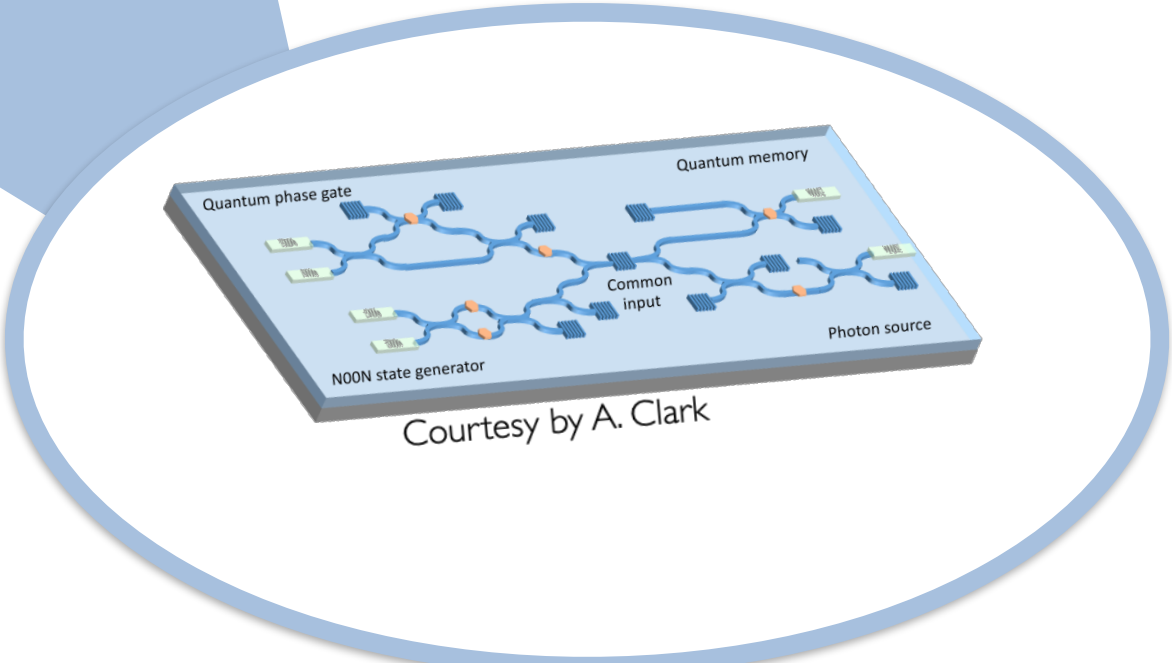
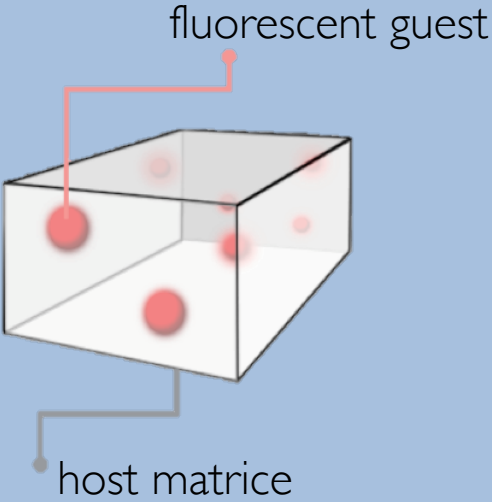
- Easy & cheap fabrication
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...in **QUANTUM Optics**

- Q. Communication & Computing
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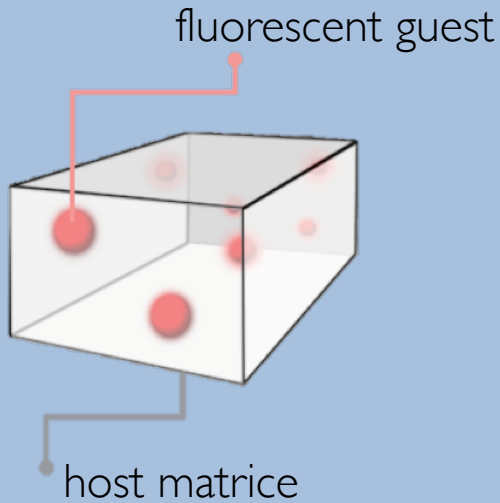


# Polyaromatic Hydrocarbons



Courtesy by A. Clark

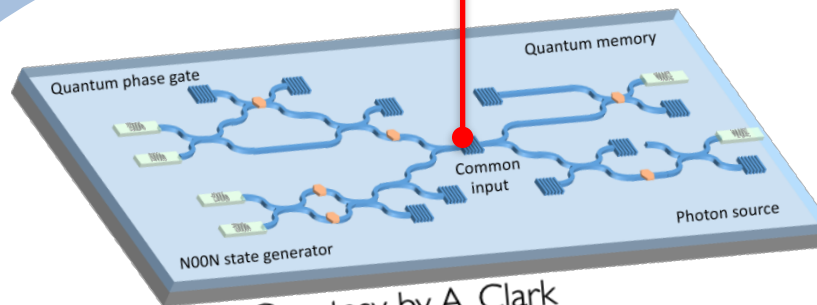
# Polyaromatic Hydrocarbons



## ★ OPTICAL PROPERTIES

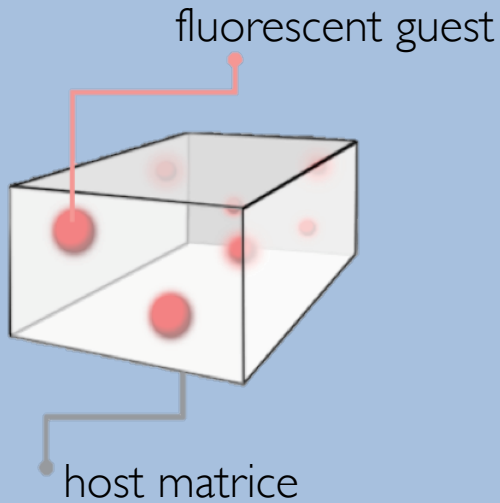
- ▶ High QY
- ▶ High single- photon rates  $> 1\text{MHz}$
- ▶ COHERENT indistinguishable photons
- ▶ Photostability

Two-Photon Interference



Courtesy by A. Clark

# Polyaromatic Hydrocarbons



## ★ OPTICAL PROPERTIES

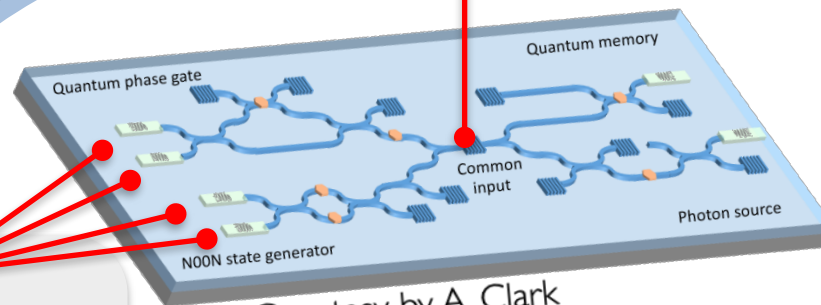
- ▶ High QY
- ▶ High single- photon rates  $> 1\text{MHz}$
- ▶ COHERENT indistinguishable photons
- ▶ Photostability

Two-Photon Interference

## ★ SCALABILITY

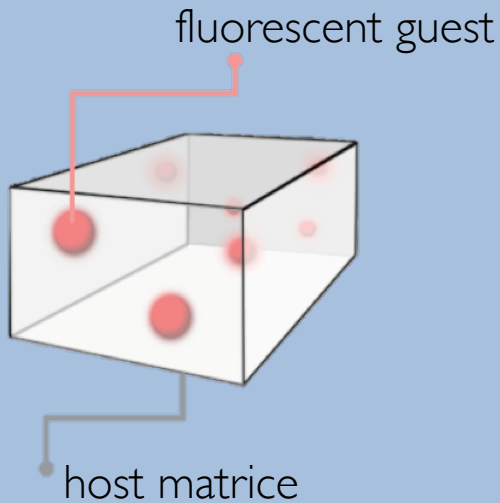
- ▶ Nominally IDENTICAL
- ▶ Tunable Frequency (Stark)

**INTEGRATION**  
multiple emitters





# Polyaromatic Hydrocarbons



## ★ OPTICAL PROPERTIES

- ▶ High QY
- ▶ High single- photon rates > 1MHz
- ▶ COHERENT indistinguishable photons
- ▶ Photostability

Two-Photon Interference

**COMING SOON!**

Review on Molecules  
*Toninelli et al,*  
about to be submitted

## ★ SCALABILITY

- ▶ Nominally IDENTICAL
- ▶ Tunable Frequency (Stark)

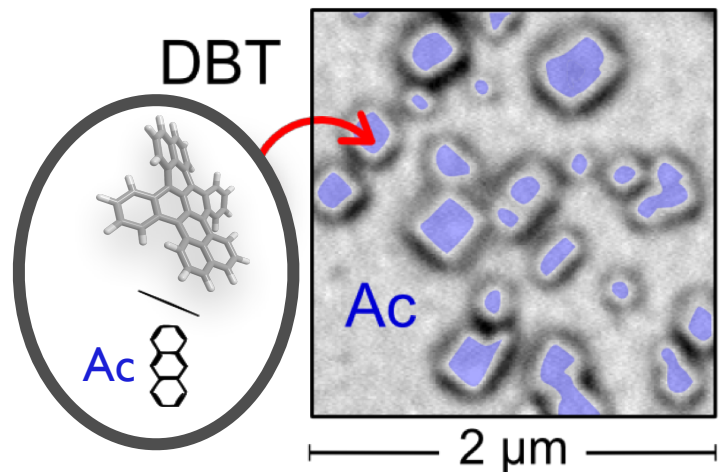
**INTEGRATION**  
multiple emitters



# Nanostructured Emitter

## Dibenzoterrylene (DBT) in Anthracene (Ac)

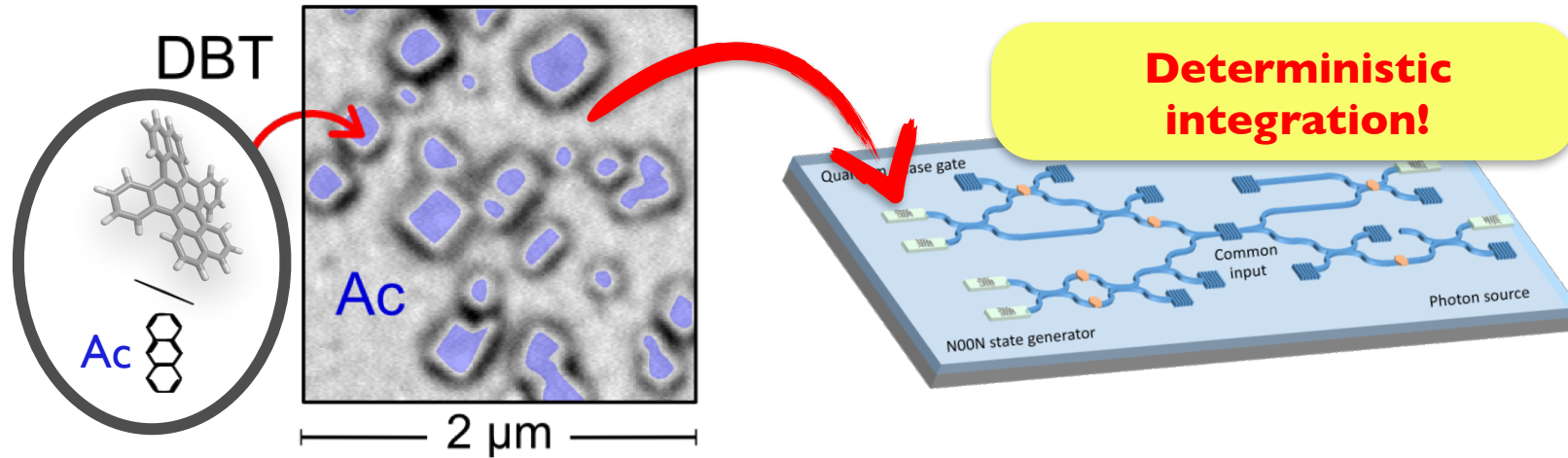
Pazzagli et al, ACS Nano (2018)



# Nanostructured Emitter

Pazzagli et al, ACS Nano (2018)

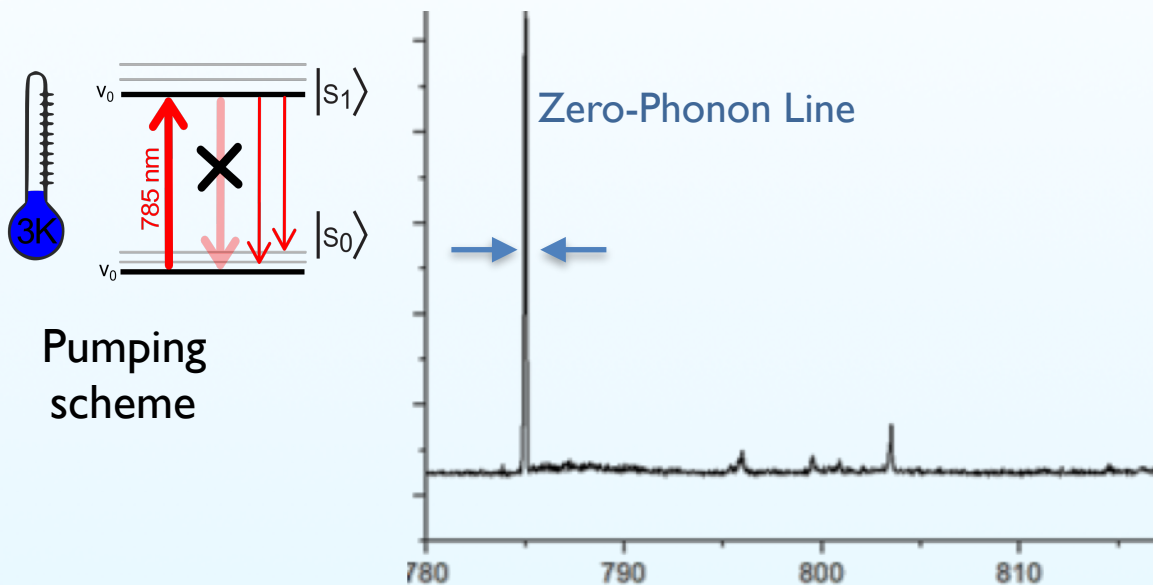
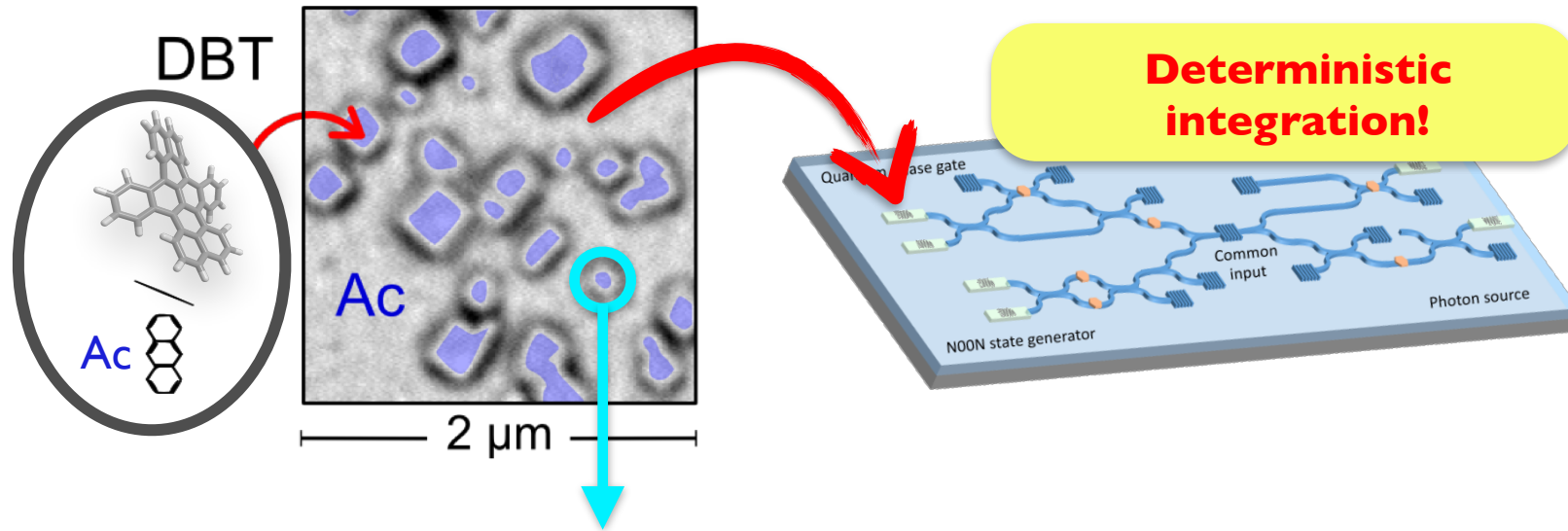
## Dibenzoterrylene (DBT) in Anthracene (Ac)



# Nanostructured Emitter

Pazzagli et al, ACS Nano (2018)

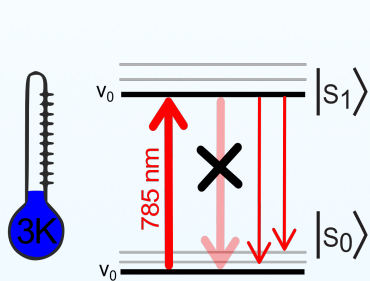
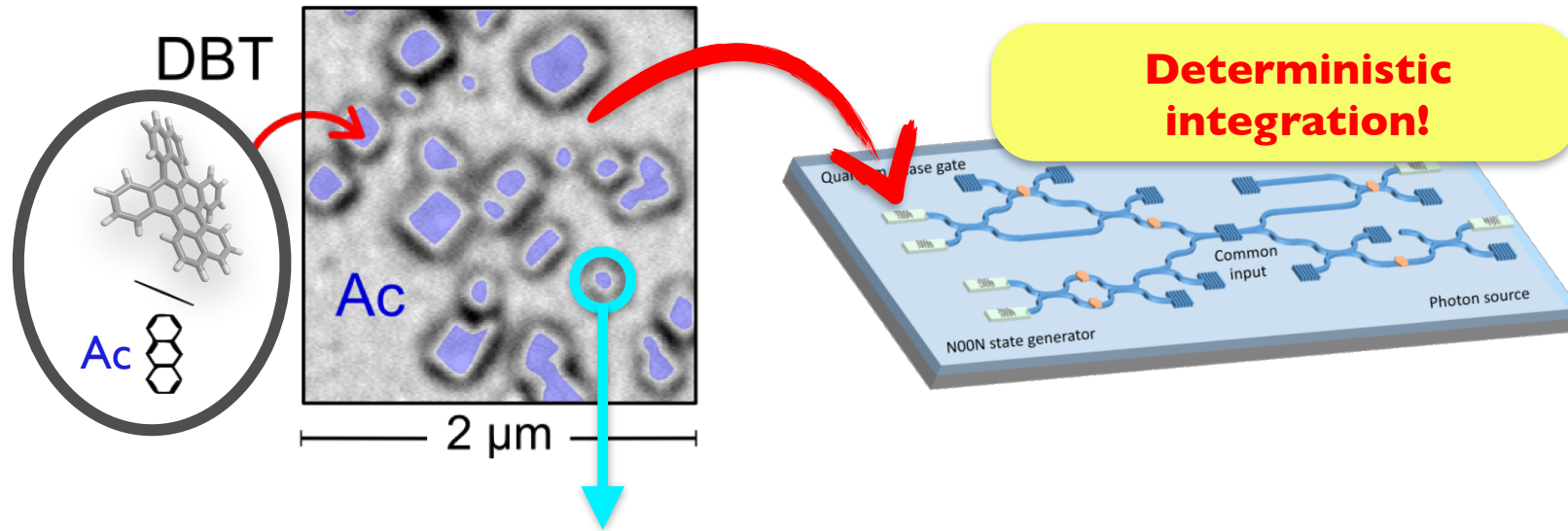
## Dibenzoterrylene (DBT) in Anthracene (Ac)



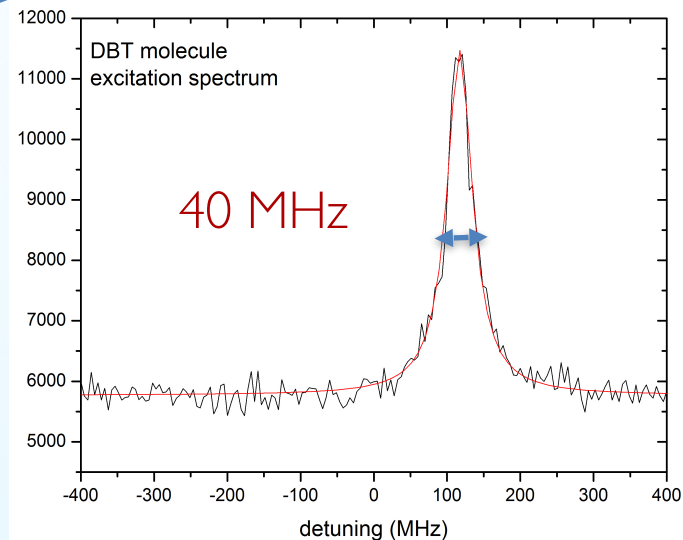
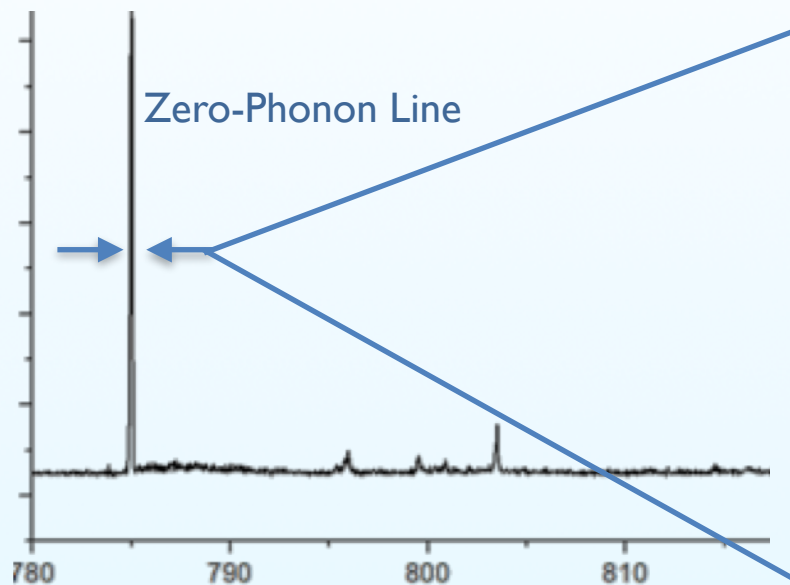
# Nanostructured Emitter

Pazzagli et al, ACS Nano (2018)

## Dibenzoterrylene (DBT) in Anthracene (Ac)



Pumping scheme

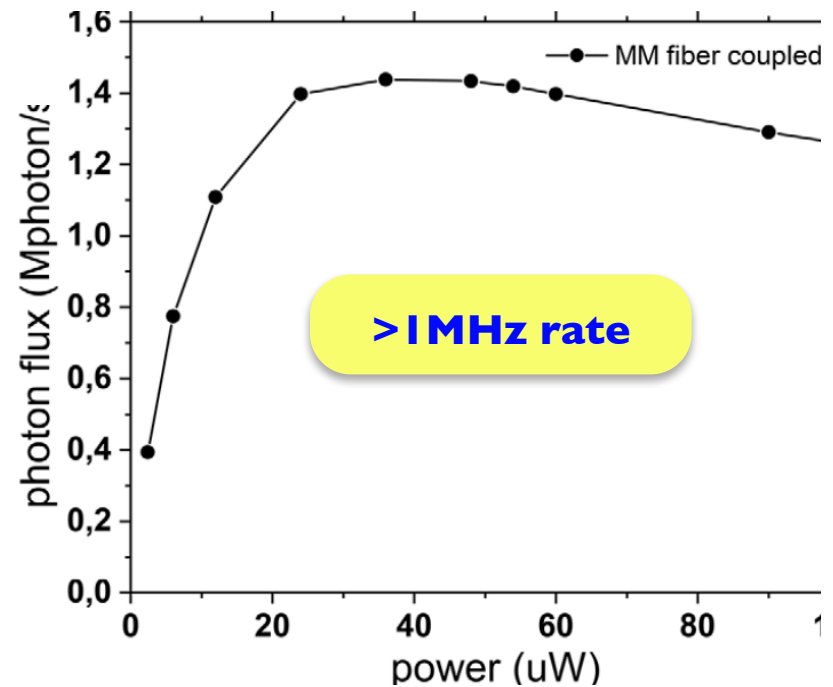
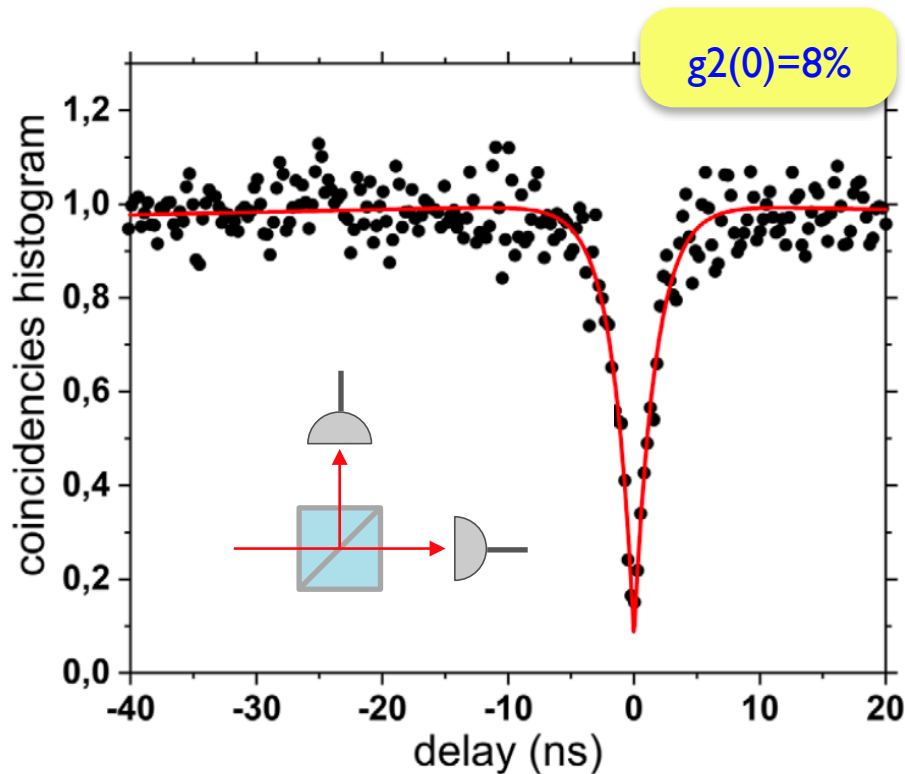


# Nanostructured Emitter

## Dibenzoterrylene (DBT) in Anthracene (Ac)

Pazzagli et al, ACS Nano (2018)

Lombardi et al, Adv. Quantum Technol. (2019)



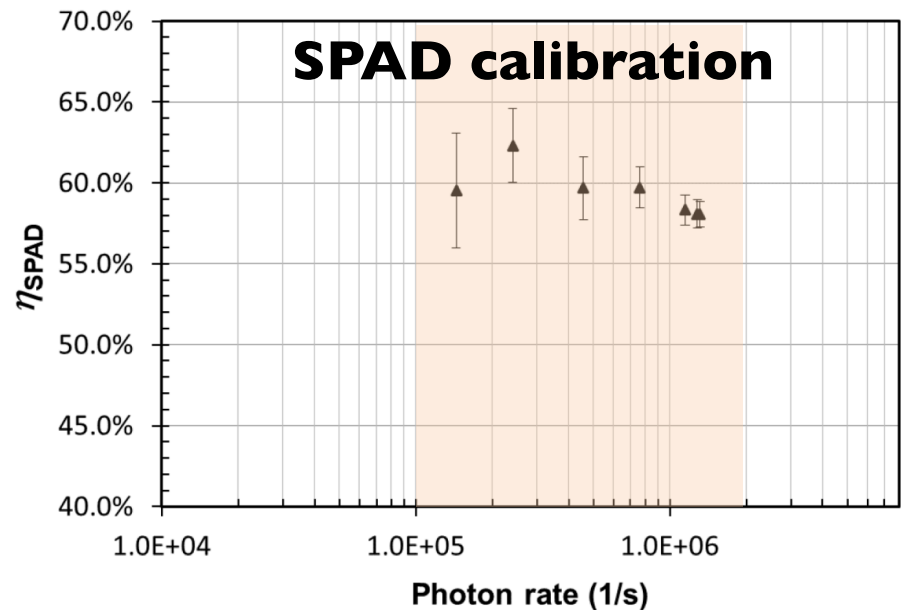
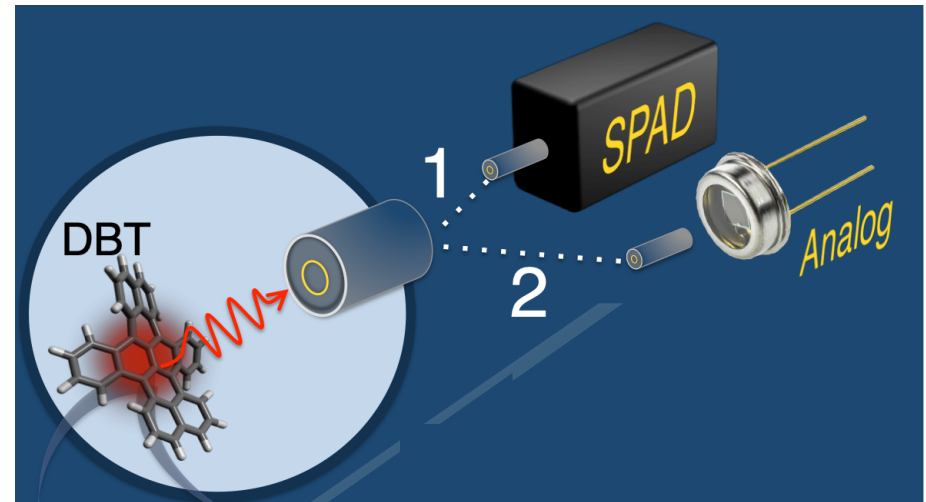
# Single Molecules for **Quantum Radiometry** (PTB)

linewidth < **2nm**

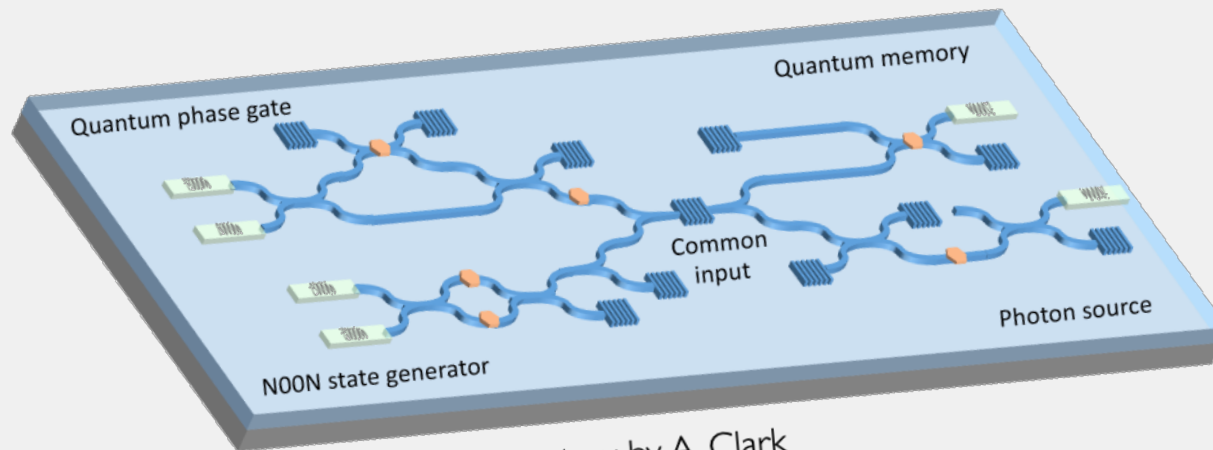
**$g_2(0) < 0.1$**   
@ maximum photon rate

rate > **1 MHz**

**Constant adjustable flux**  
for calibrating  
single-photon detector



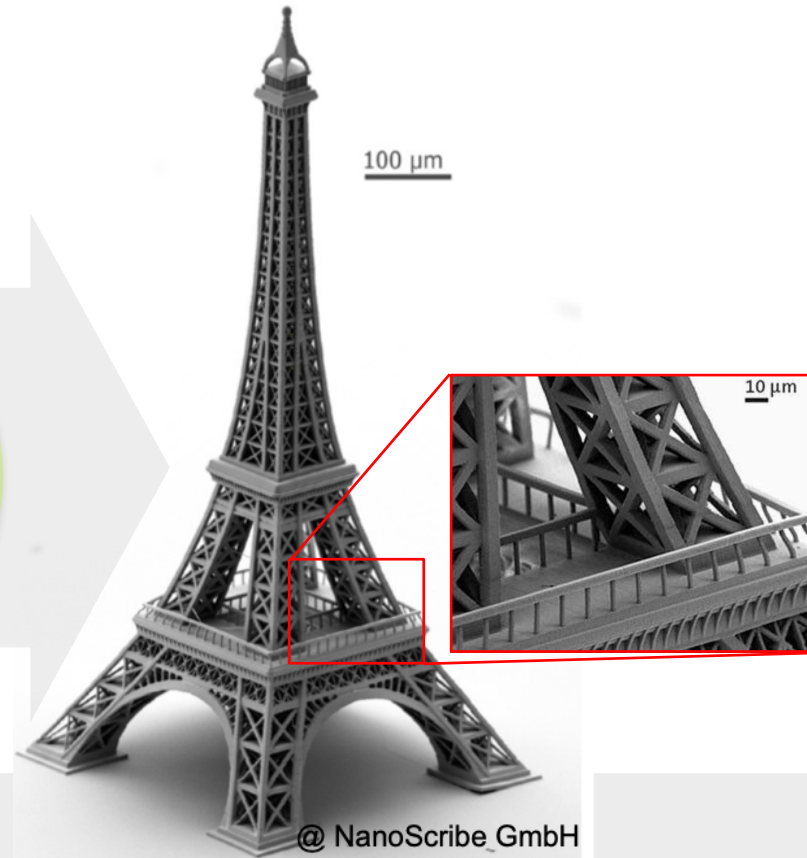
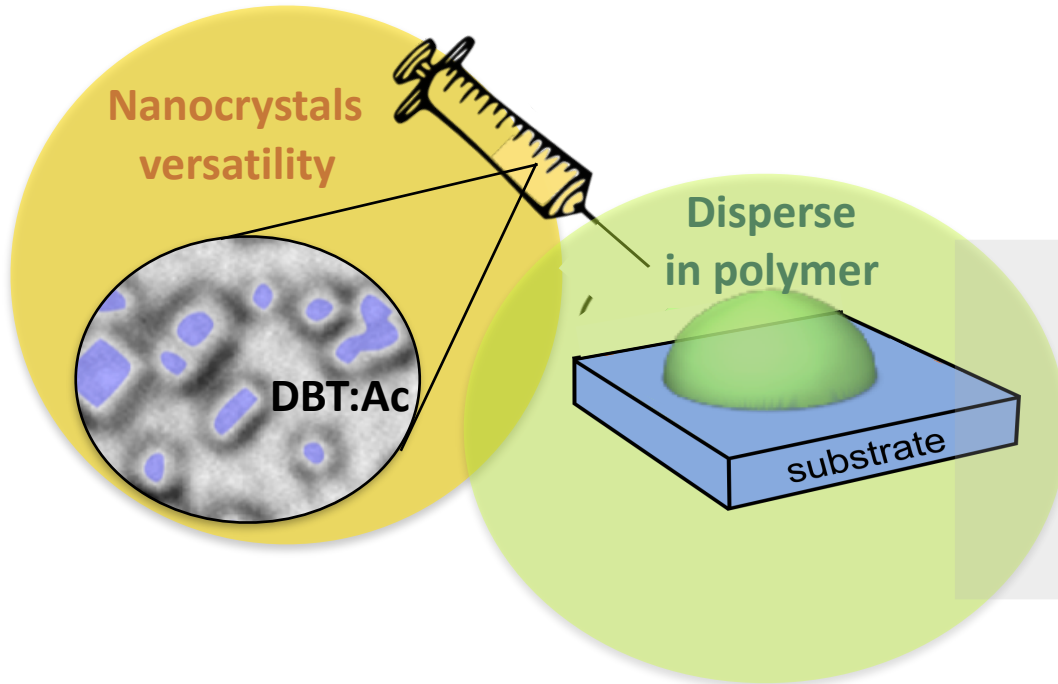
# - Integrated Platform -



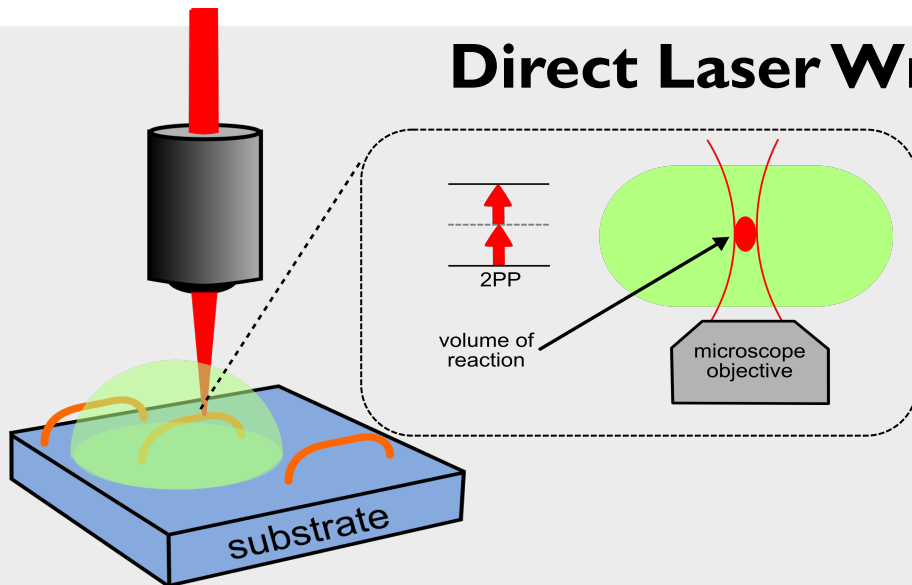
Courtesy by A. Clark



# Novel approach

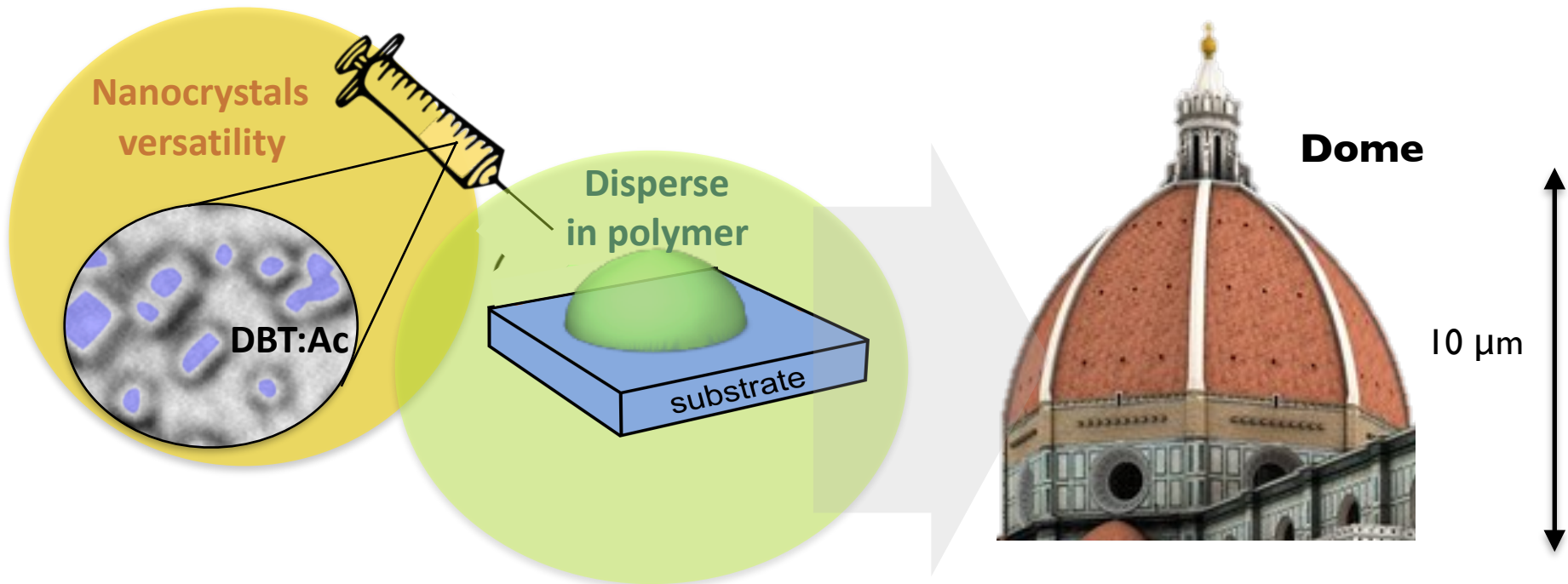


## Direct Laser Writing

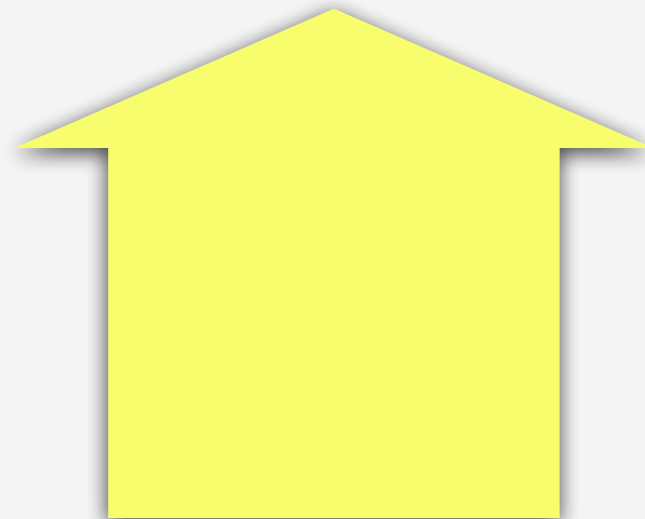
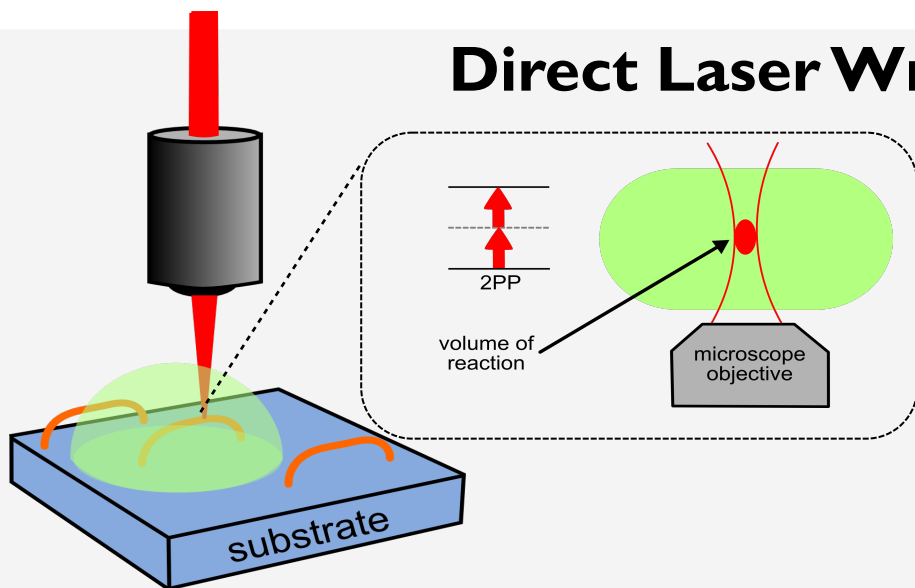


- ▶ **Fast** fabrication
- ▶ **High resolution** below diffraction limit
- ▶ **Inexpensive fabrication**
- ▶ **3D writing**

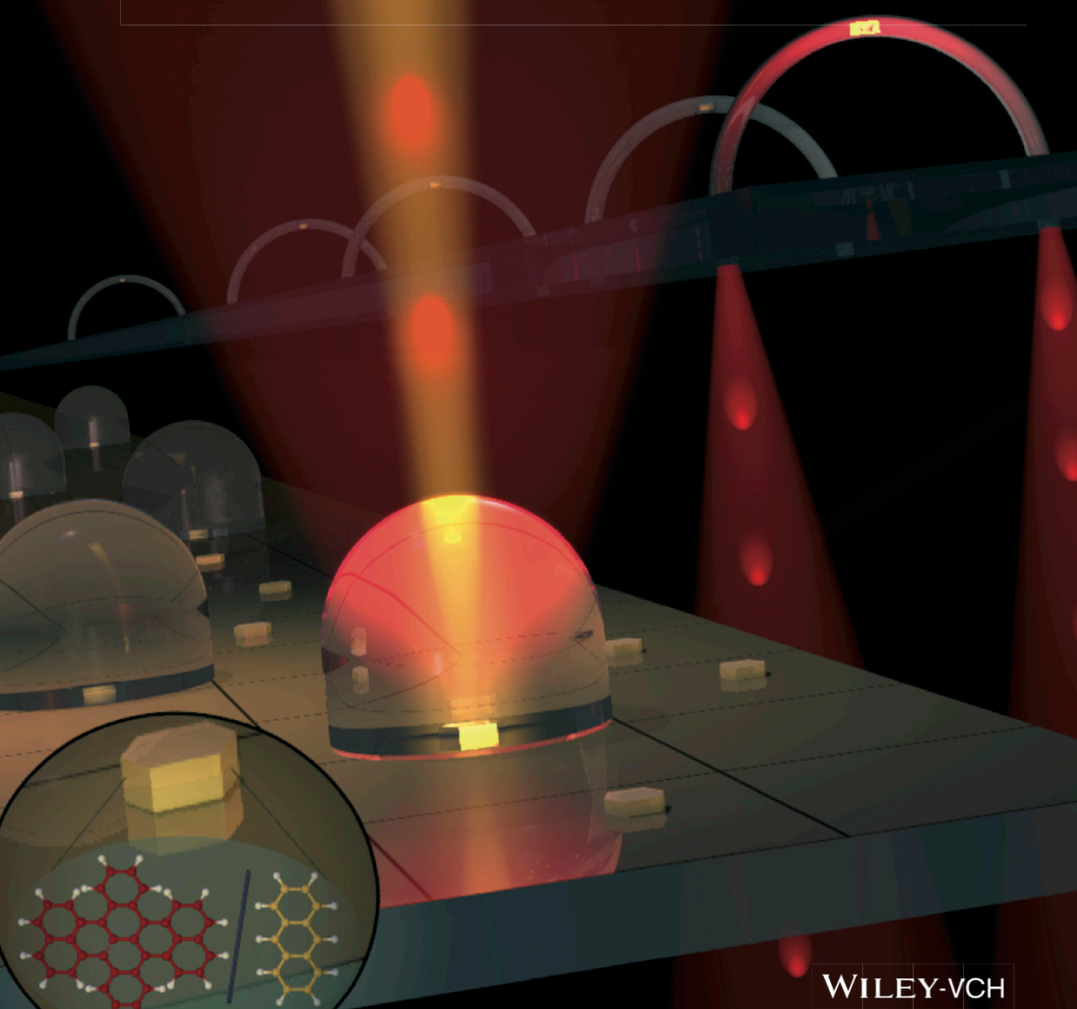
# Novel approach



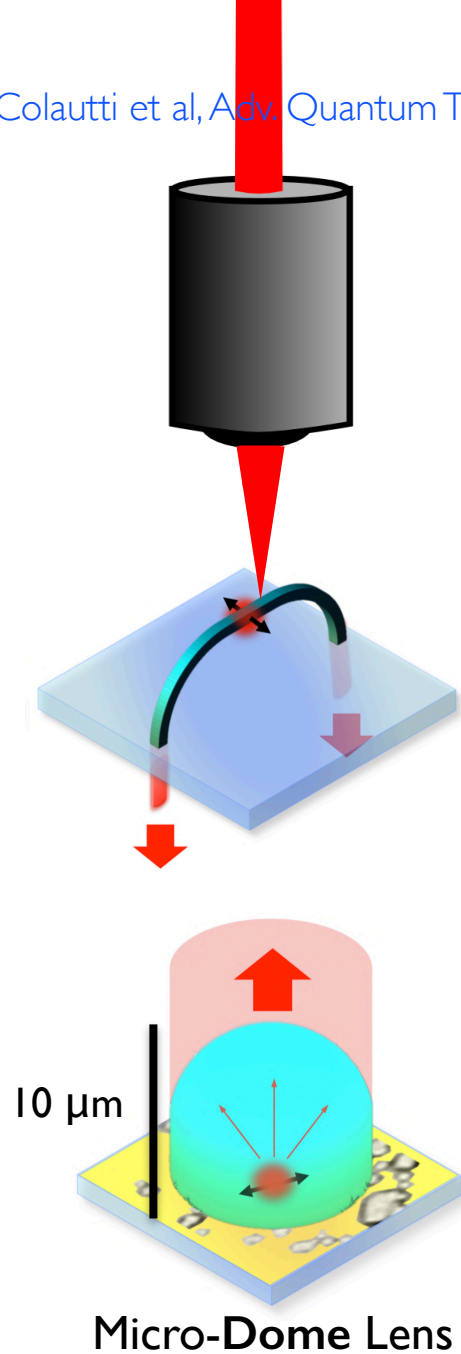
# Direct Laser Writing



# ADVANCED QUANTUM TECHNOLOGIES



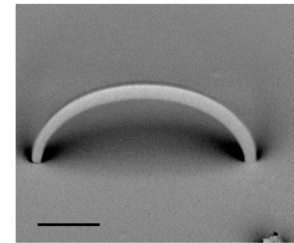
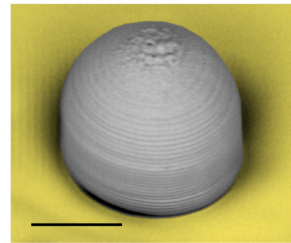
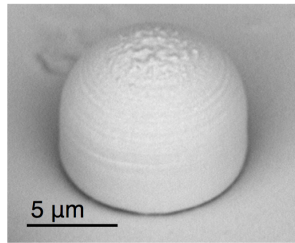
Colautti et al, Adv. Quantum Technol. (2020)



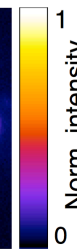
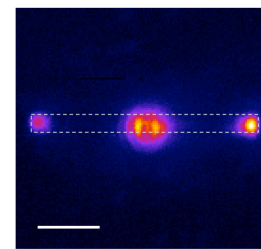
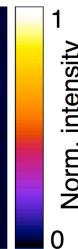
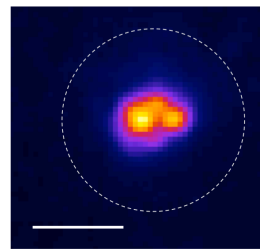
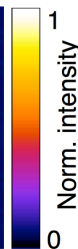
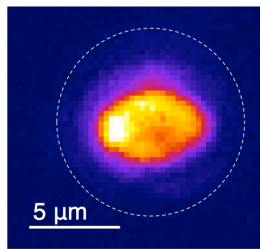
Micro-Dome Lens

# Experimental results

Colautti et al, Adv. Quantum Technol. (2020)



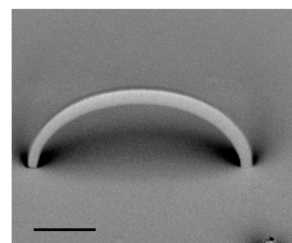
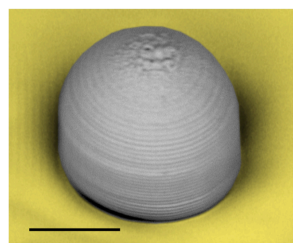
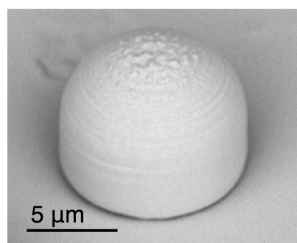
SEM images



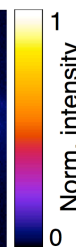
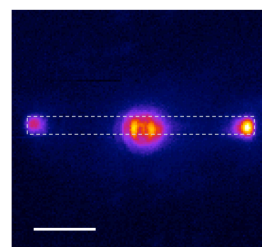
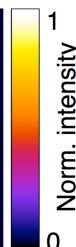
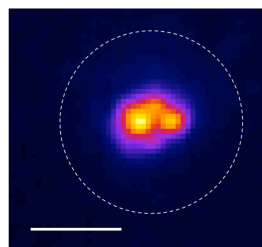
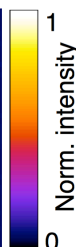
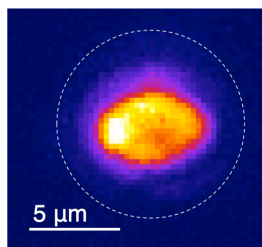
Fluorescence maps

# Experimental results

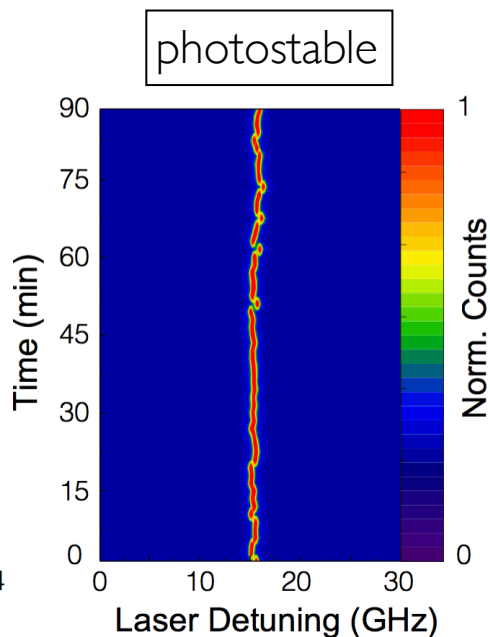
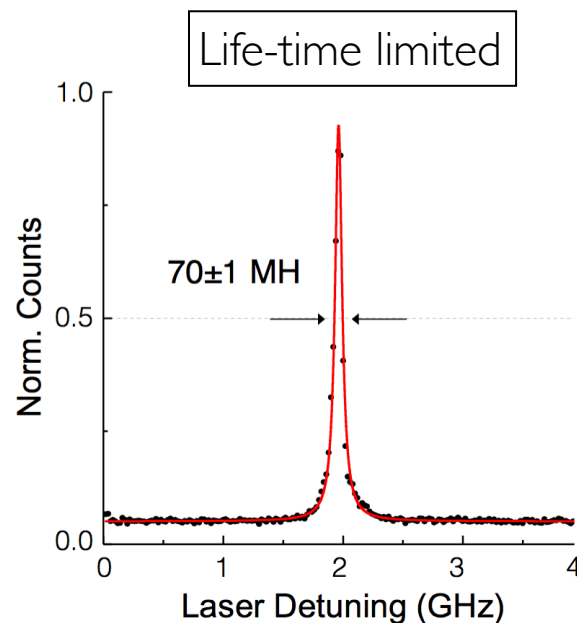
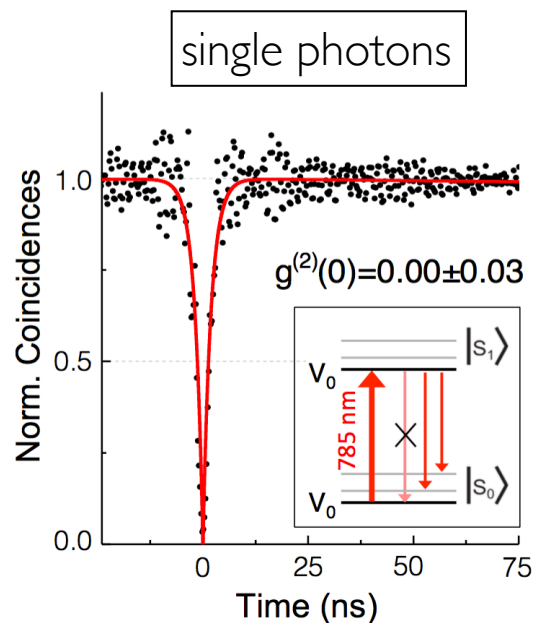
Colautti et al, Adv. Quantum Technol. (2020)



SEM images

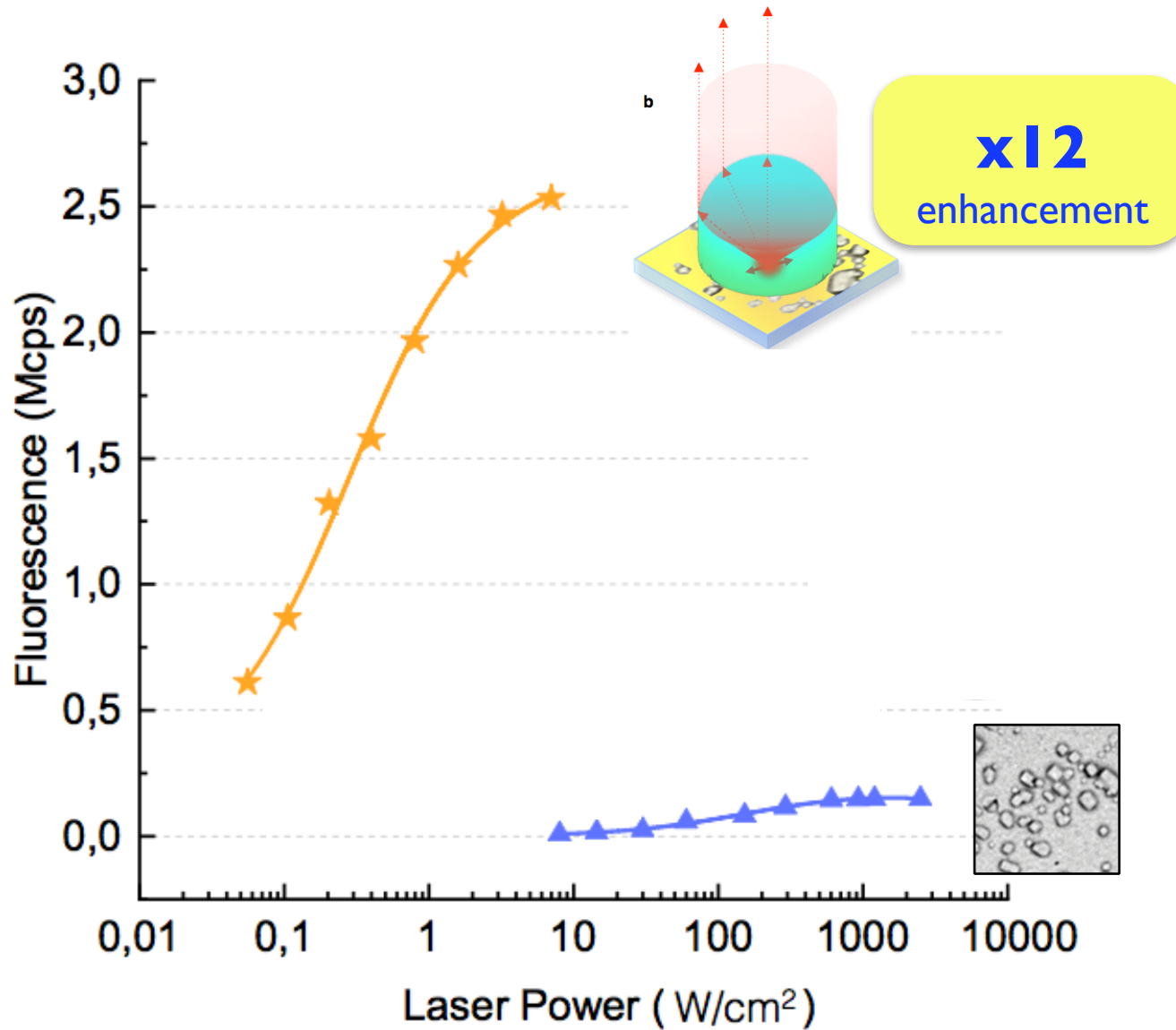


Fluorescence maps



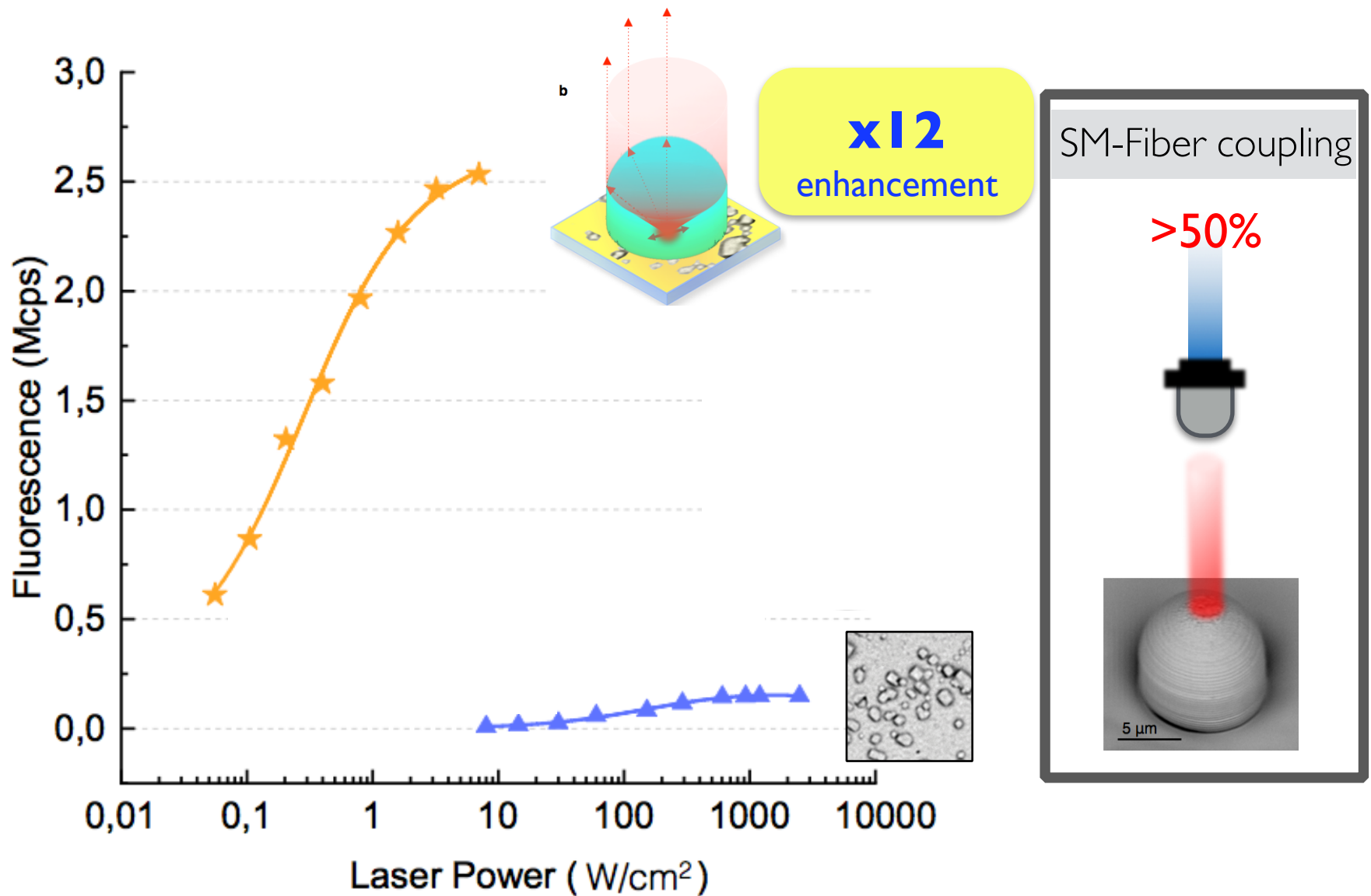
# Experimental results

Colautti et al, Adv. Quantum Technol. (2020)



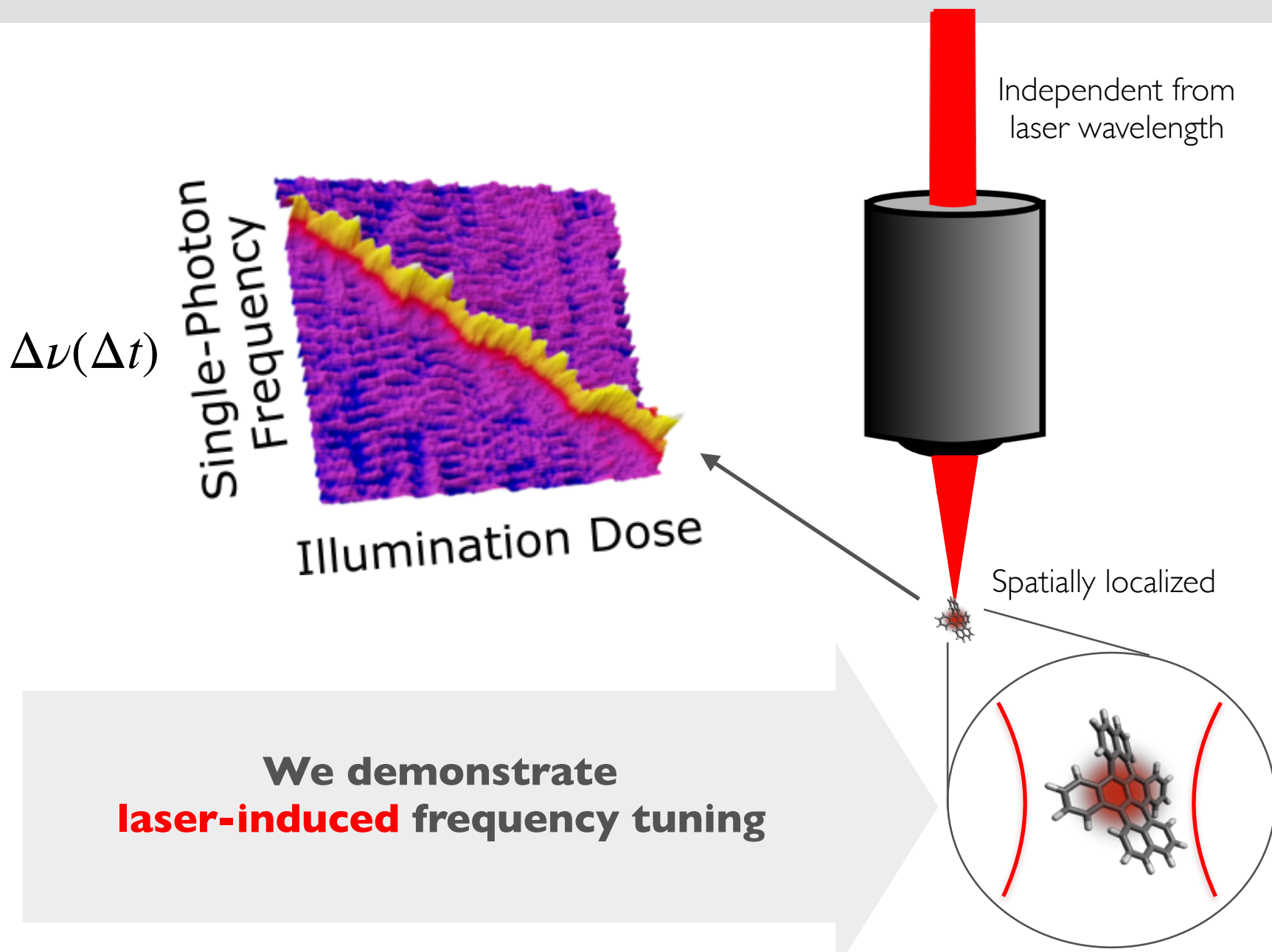
# Experimental results

Colautti et al, Adv. Quantum Technol. (2020)

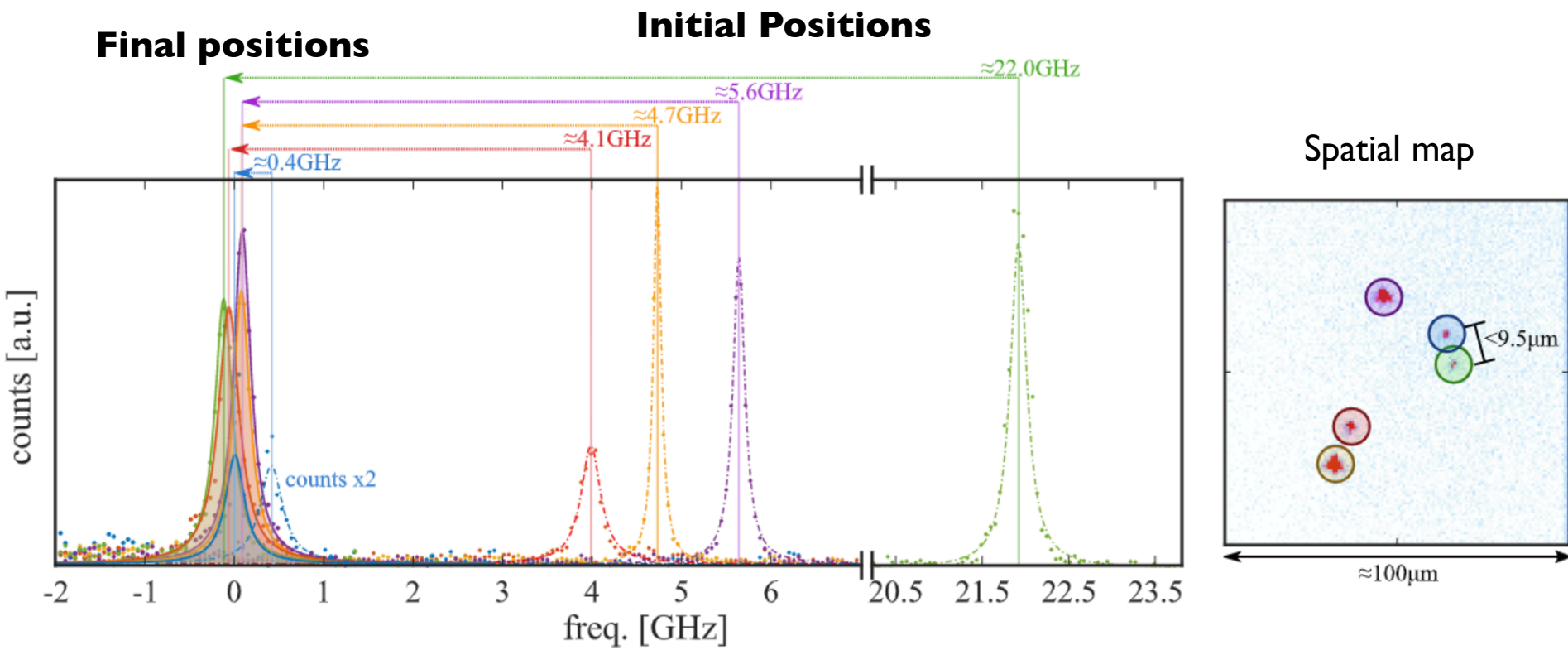


# Laser-induced frequency tuning

Colautti et al, ACS Nano (2020)

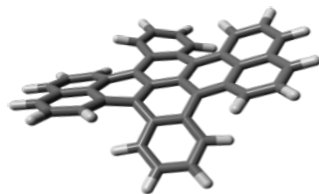






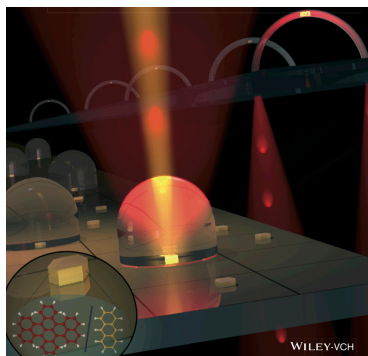
# Conclusions

Emitter



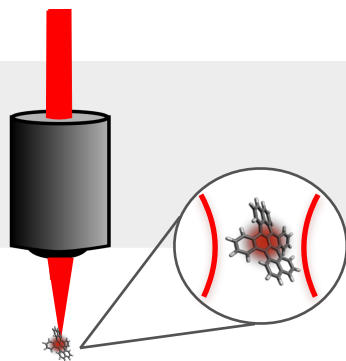
◆ **Reliable single photon source**

3D integration



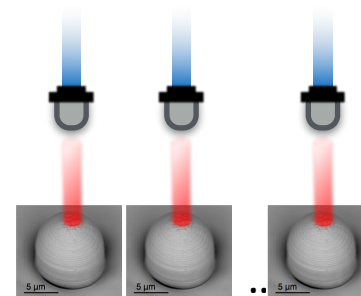
- ◆ **Compatible with the emitter**
- ◆ **Good photonic performance**

Laser-induced tuning



## Outlook

➤ Multiple emitters



# Quantum Nanophotonics Group



Murtaza Ghulam



Prosenjit Majumder

## Other collaborations

M. Agio et al. (Siegen)

N. Van Hulst (Barcelona)

O. Benson et al. (Berlin)

M. Lopez & S. Kueck (PTB)

I. P. De Giovanni (INRIM)



D. Wiersma



S. Nocentini



F.S. Cataliotti

W. Pernice & A. Owyjan (Muenster)

F. Koppens, et al. (Barcelona)

M. Orrit et al., (Leiden)

A. Clark et al., (London)

B. Kozankiewicz et al., (Krakow)

A. Gourdon et al., (Toulouse)