

# Bio-Lasers

*An Emerging Field Bridging Photonics & Biomedicine*

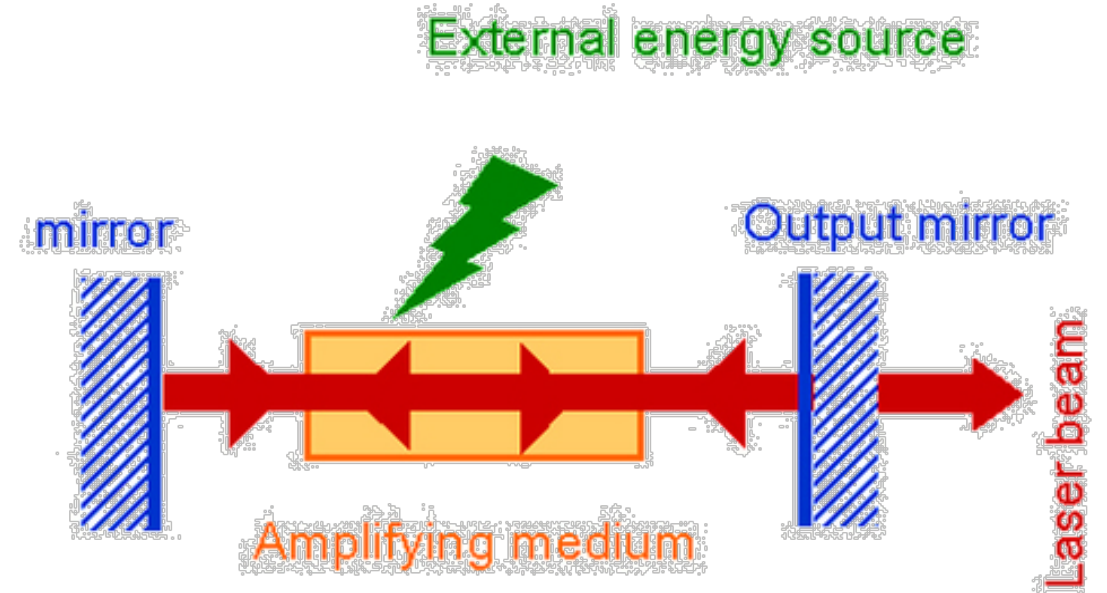
Yu-Cheng Chen, PhD

# What is a Laser?

## ■ Major Components

1. Pump source
2. Gain media
  - Crystal, dyes, gas
  - semiconductor
3. Optical cavity
  - Fabry-Perot (mirrors)
  - photonic crystals
  - ring-resonators

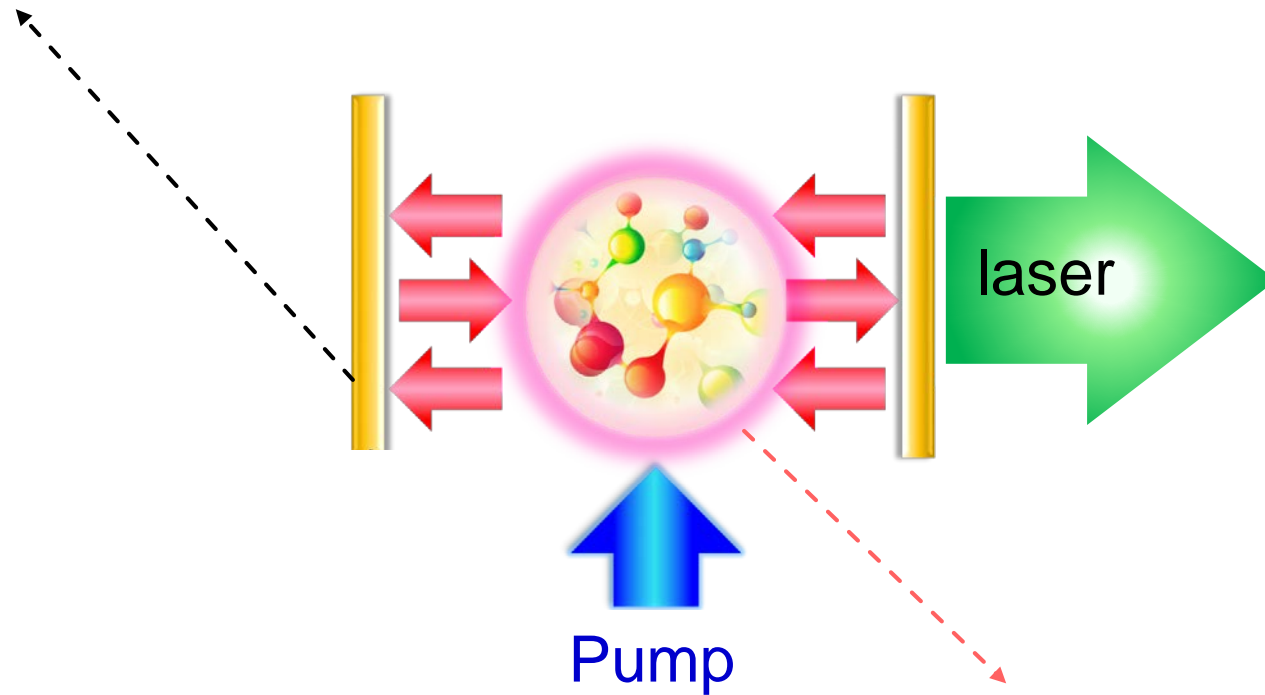
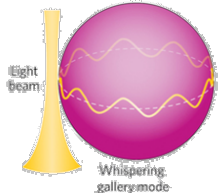
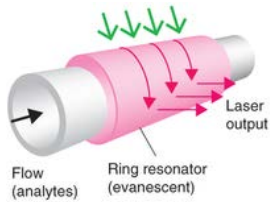
■ Wide applications in medicine, communications, imaging, industry, electronics, and military.



# Concept of Biolasers

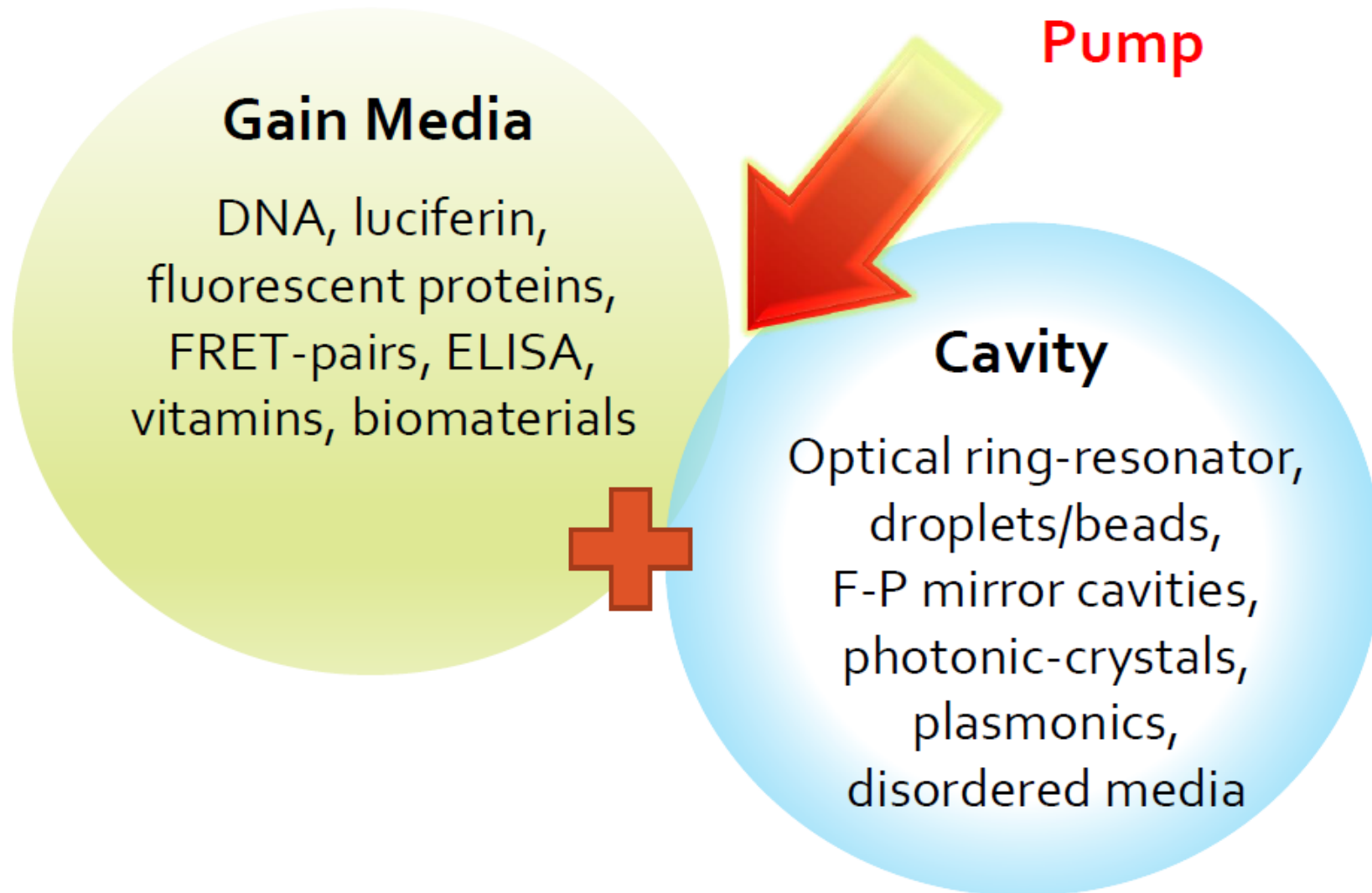
**Optical cavity:**  
FP mirrors, ring resonators

- Utilize laser as the sensing signal
- Amplification of subtle changes



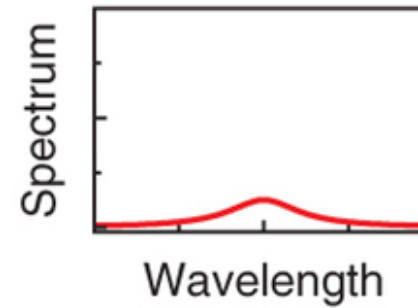
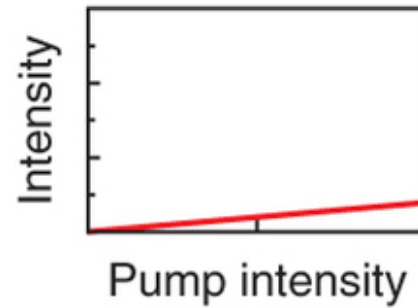
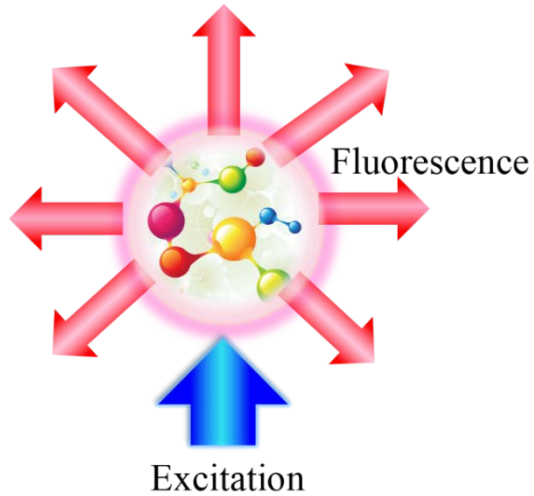
**Gain media:**  
biologically related materials

# Concept of Bio-laser

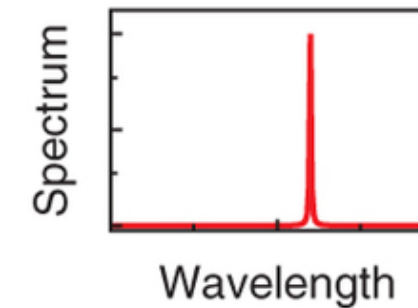
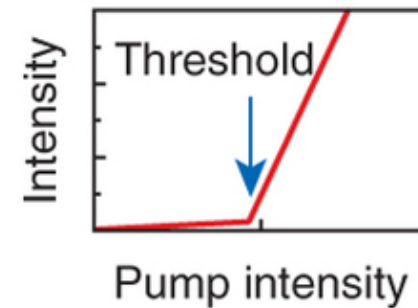
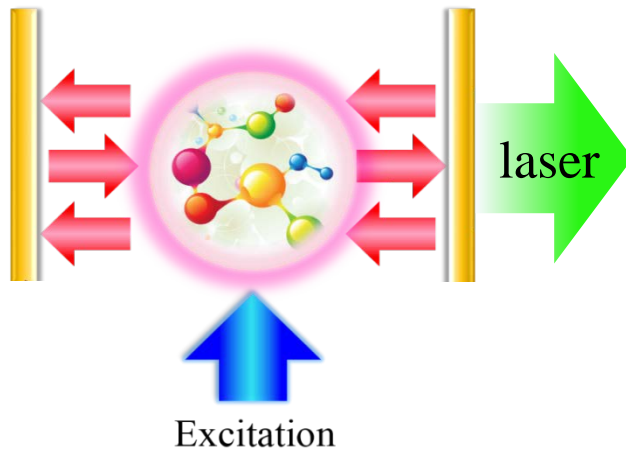


Any fluorescent materials in fluorescence-based detection can potentially be used.

# Fluorescence vs. Laser-based Detection



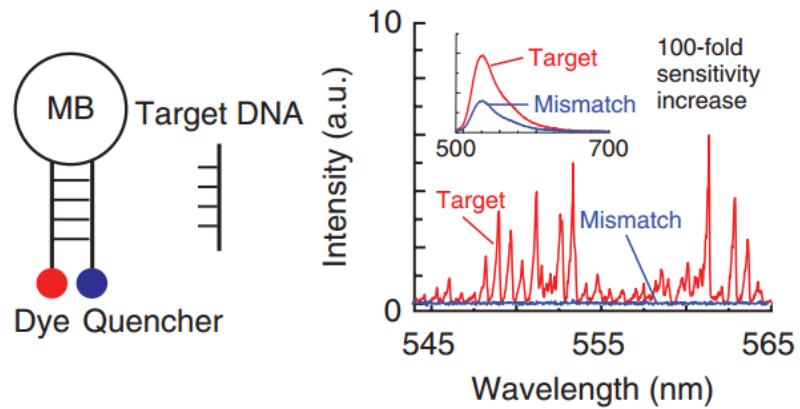
- Threshold behavior
- Narrow linewidth
- Strong intensity
- High controllability
- High contrast and SNR



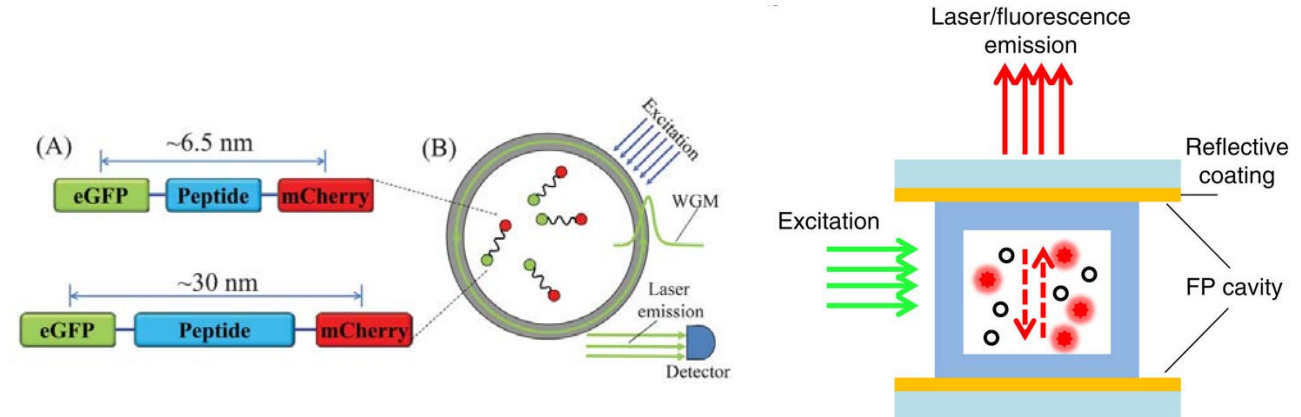
  
**Sensing & Imaging**



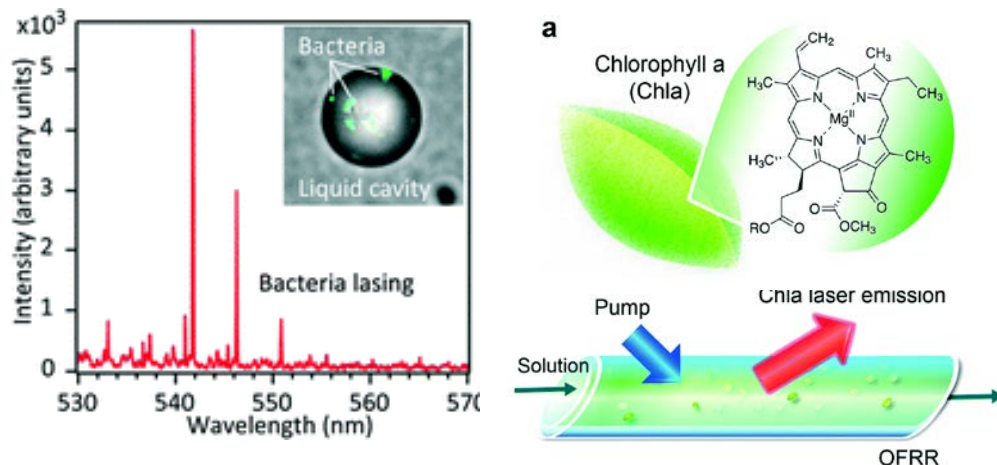
# Overview- Biomolecular-based Biolaser



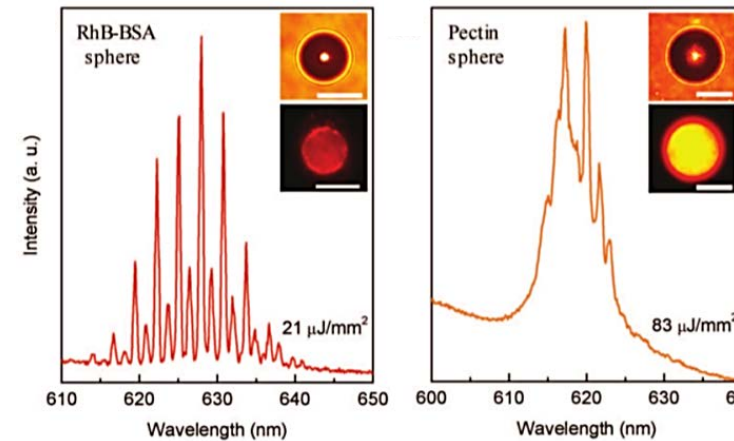
DNA biolaser for analysis of biomolecular interactions  
Y. Sun, X. Fan, *Angewandte Chemie* (2012)



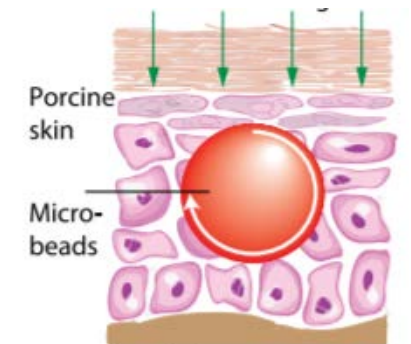
FRET protein biolasers. Q. Chen, et al. *Lab Chip* (2013)  
ELISA biolasers. X. Wu, et al. *Nat. Commun.* (2014)



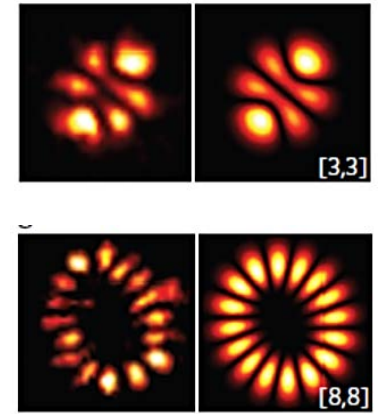
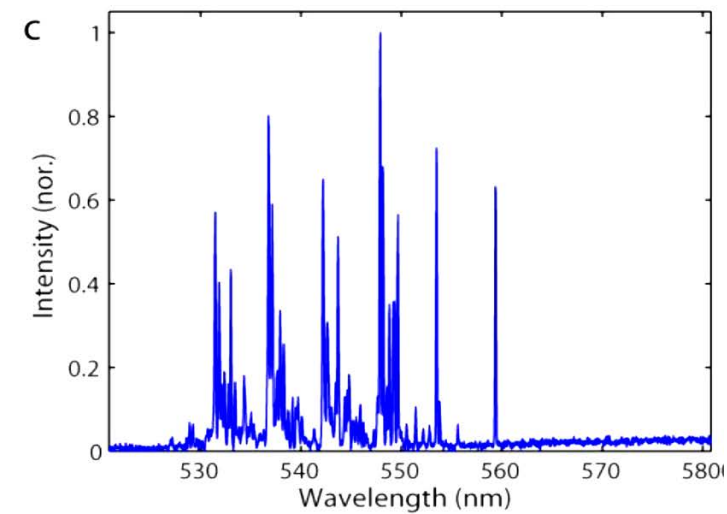
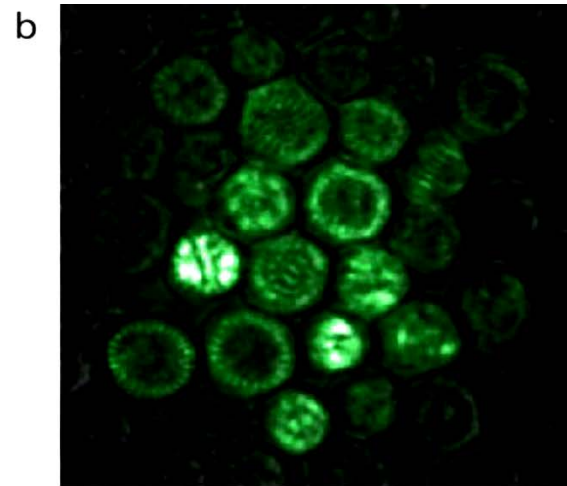
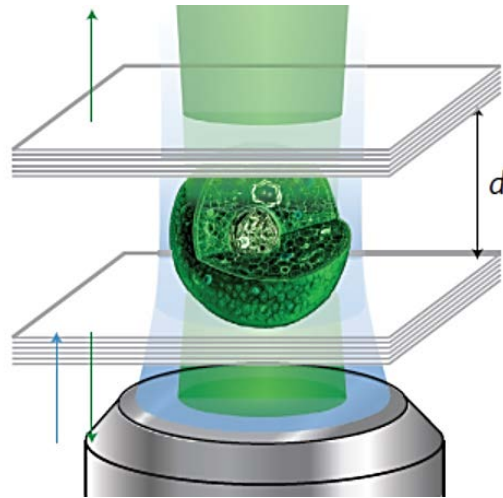
Biolasing in bacteria. Jonáš, et al. *Lab Chip* (2014)  
Lasing with chlorophylls. Chen, et al. *Lab Chip* (2016)



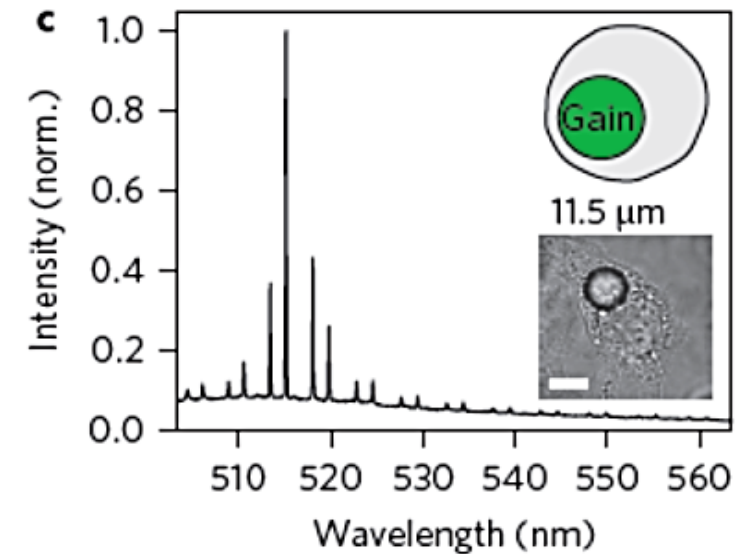
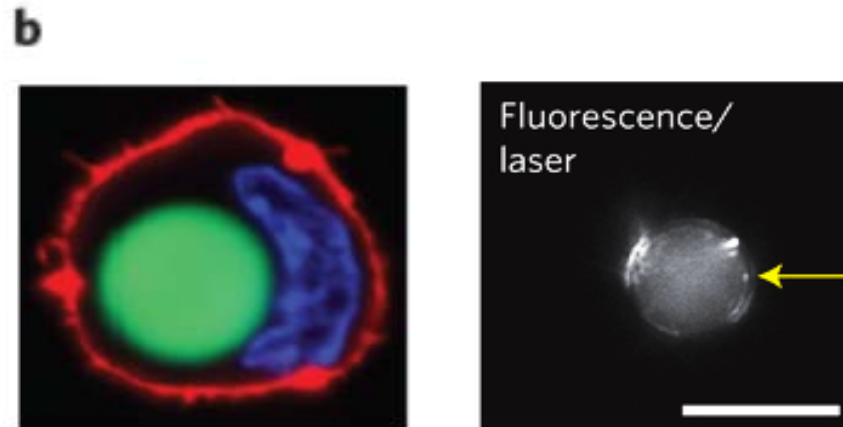
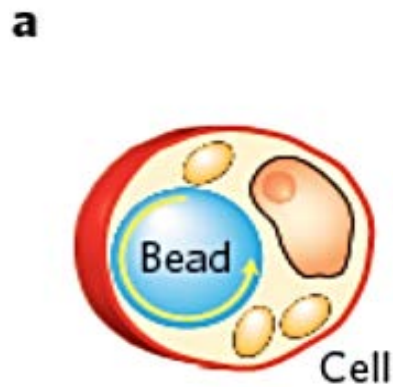
Biomaterial synthesized micro-biolaser, Ta, et al. *Adv. Opt. Matt.* (2017)  
Biomaterial implantable biolaser, Humar, et al. *Optica* (2017)



# Overview- Cellular-based Biolaser



Single cellular lasers. M. Gather, et al. *Nat. Photon.* (2011).



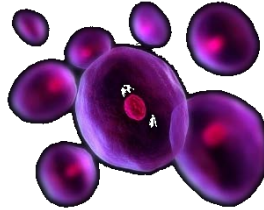
Intracellular microlasers. M. Humar, et al. *Nat. Photon.* (2015).

# Aim: Bio-functional Laser-based Sensing. Imaging

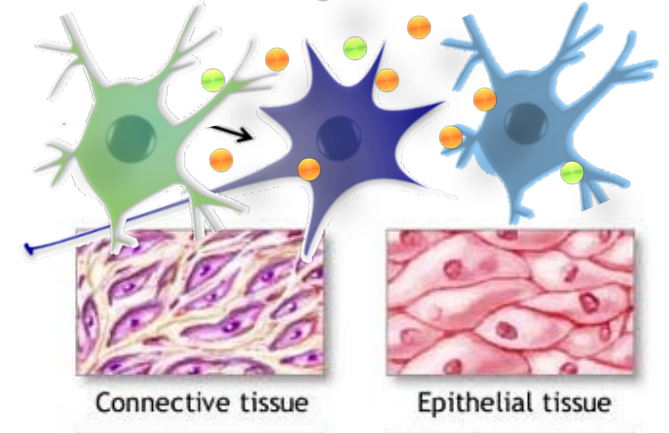
Biomolecules



Cells



Sensing in live cells/  
Networks/ tissues



## ■ Significance of cell/tissue-biolasers:

- Monitor/ Detect subtle biological transients in cells/tissue
- Improved signal-to-background ratio (contrast) and sensitivity
- Mimics real complex biological environment in body
- Highly sensitive on-chip biosensing/ biomedical imaging

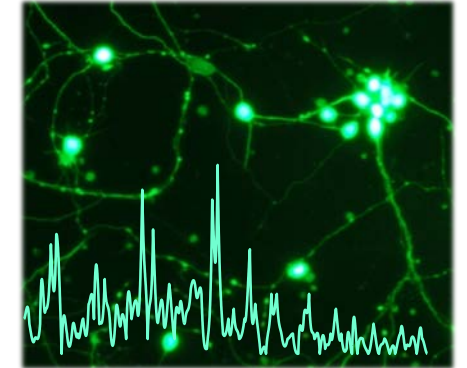
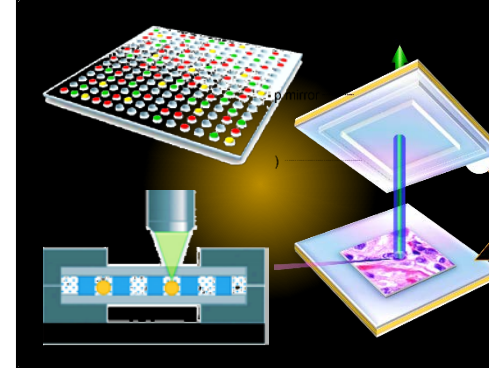
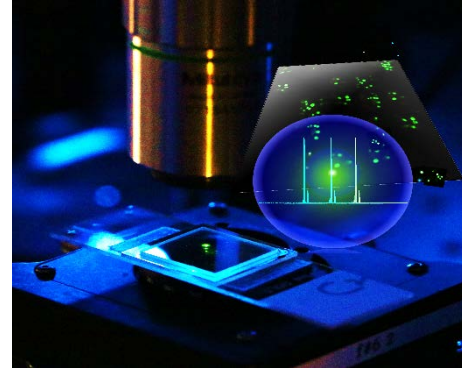
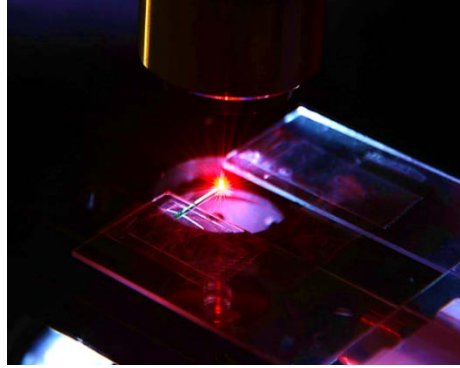
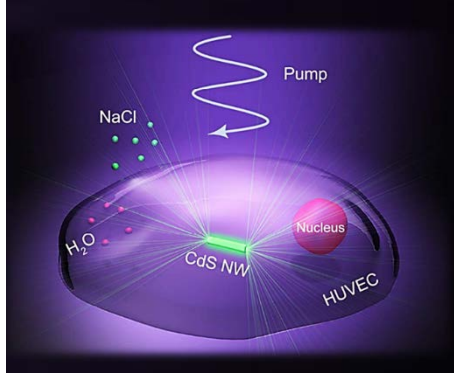
Demonstration of  
Bio-Laser  
Lasing on/off

First Application of Bio-  
Laser: Biosensing+  
imaging

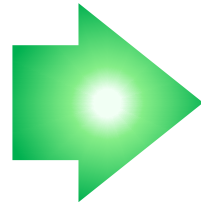
Advanced biolaser  
device/systems  
Imaging/ Sensing  
analysis



# Recent Projects in Biolasers



- **High sensitivity**
- **High contrast**
- **Narrow linewidth**
- **High resolution**
- **Lasing thresholds**
- **Controllability**



- **Optics:** Super-resolution imaging, laser mode science, micro/nano laser devices.
- **Biology:** tissue engineering, single cell analysis, monitoring biological networks.
- **Biomedicine:** On-chip devices, cancer diagnosis, drug testing in tissues.

# Outlook

## Fundamental Science

*The mechanism of biolaser*

*Biological significance of laser patter*

*Engineering of micro-nano lasers*

*Super-resolution imaging*

## Technology Development

*Advanced laser-imaging system*

*Biolaser-on chip devices*

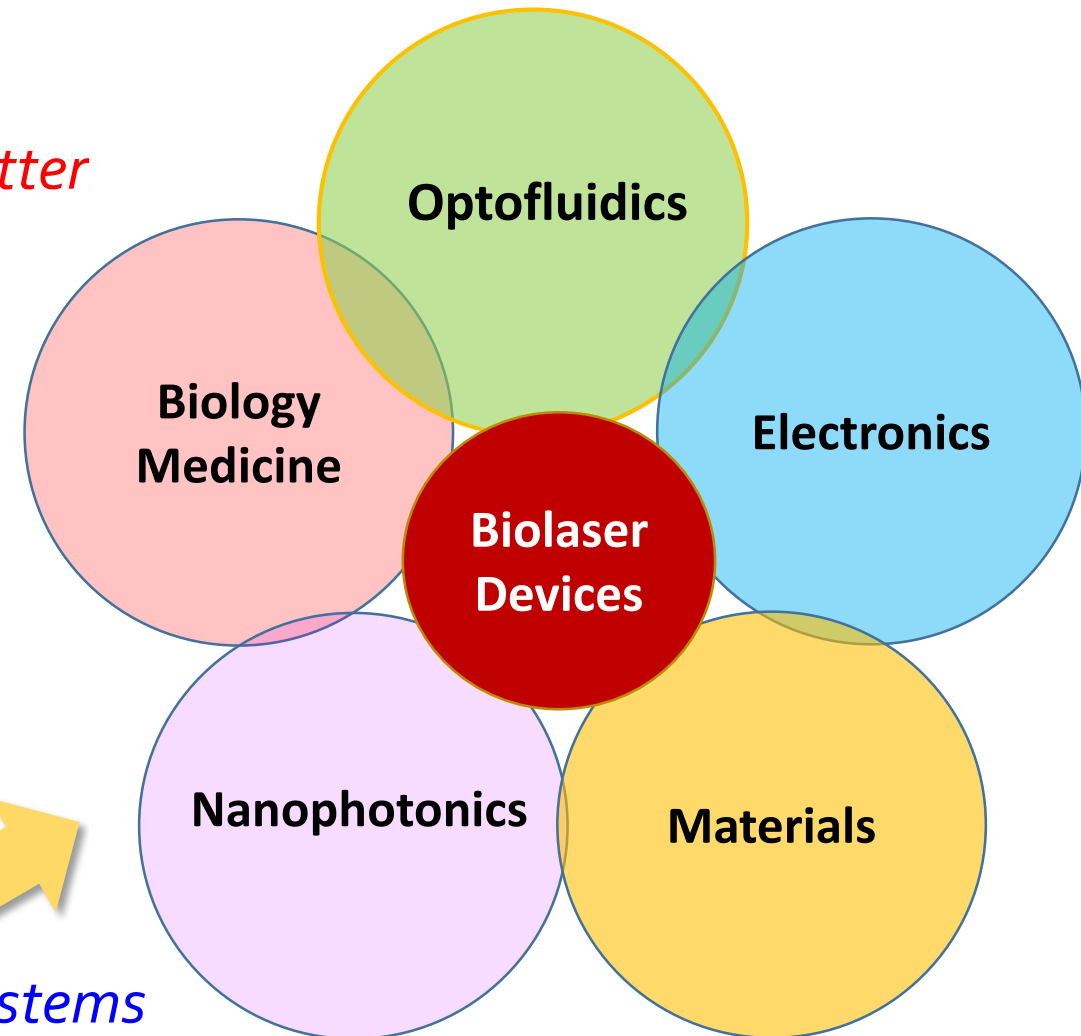
*Integration with electronics*

*Wearable/ implantable biolaser systems*

*Monitoring of cancer and neurological diseases*

**BIOLASERS**

An Emergent Field



# New Lab: Opening Positions in NTU!

Biolasers, Biomedical imaging, Biosensing devices

- Fully funded PhD scholarships
- Postdoctoral research fellows



Backgrounds with Photonics, Optics, Electrical Engineering, Biomedical, or Material Science are all welcome!

