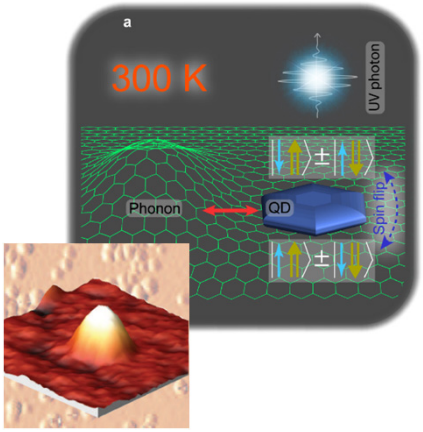
Research activities at the Laboratory of Advanced Semicondutors for Photonics and Electronics (LASPE)

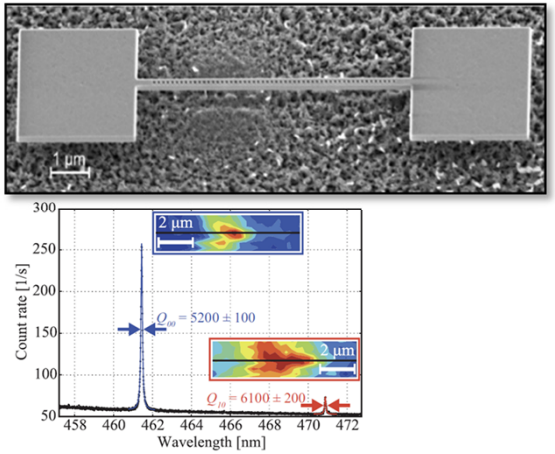
Head: Prof. Nicolas Grandjean

~15 people working on III-nitride semiconductors

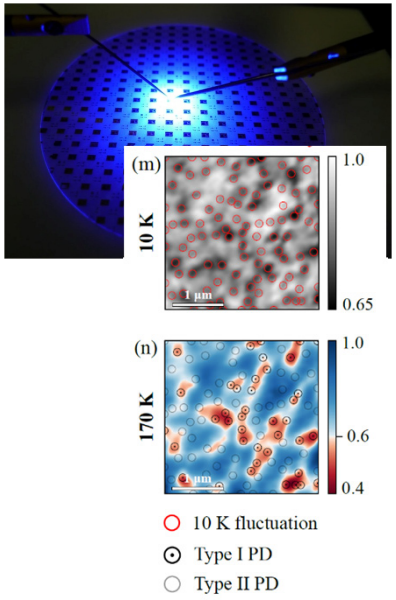
Quantum dots



Photonic crystals

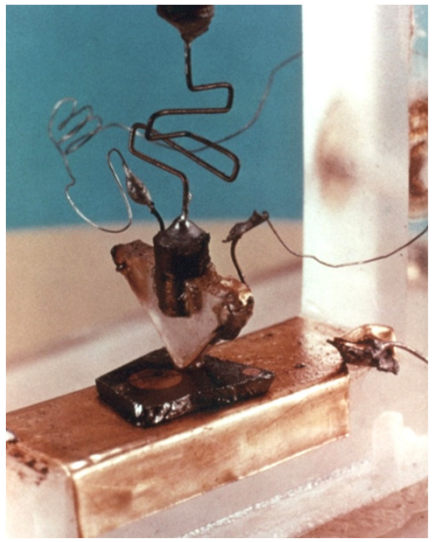


Point defects in LEDs

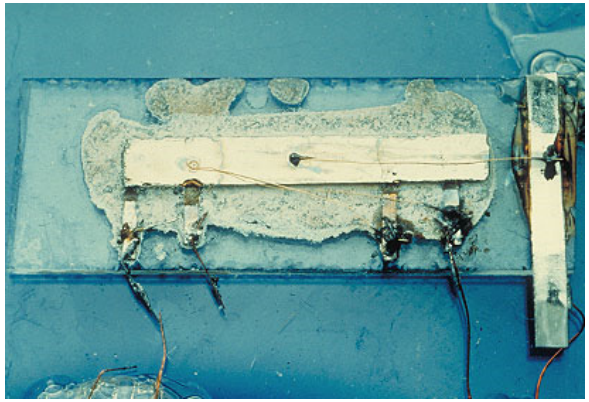


Semiconductors: a brief overview

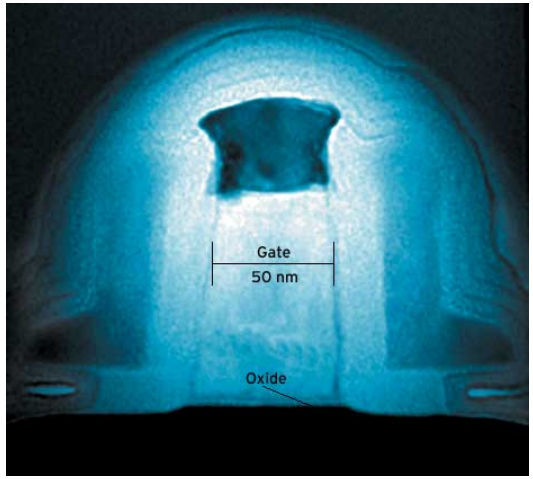
1960's → **Silicon based electronics**



1947
1st transistor (Ge-based)
Bell Labs



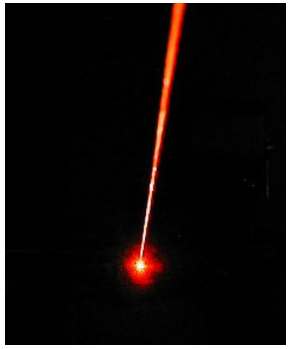
1958
1st integrated circuit
Texas Instruments



2007
Toward ultimate MOSFETs

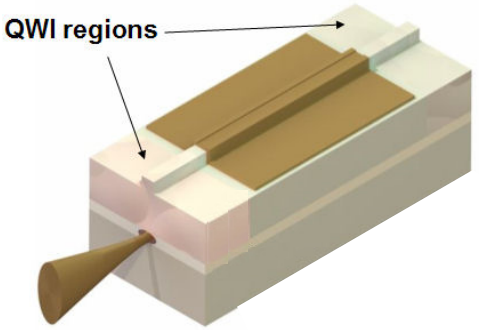
BUT not suited for light emission

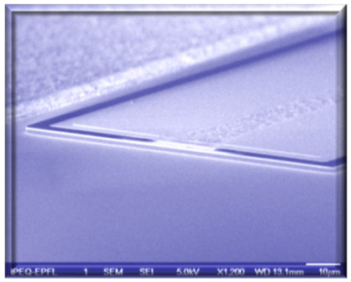
Semiconductors: a brief overview

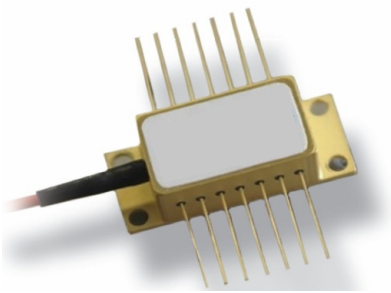


1970
1st laser diode
λ~ 780 nm
J_{thr}~ 4.3 kA/cm^2
Ioffe, Russia

1980's → **GaAs based optoelectronics**







2000

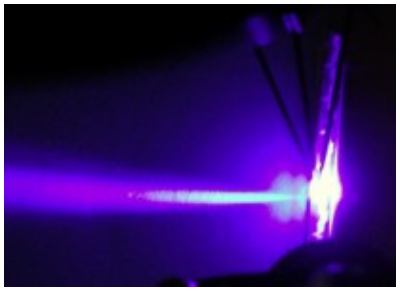
CD, DVD, Telecom

BUT light emission limited to the **Red** and **IR**

Semiconductors: a brief overview

1993

1990's → **GaN short-wavelength optoelectronics**



UV, blue, and green LEDs
High density DVD, color displays

2003

→ **White LEDs**

Semiconductors: a brief overview

Centenial light bulb

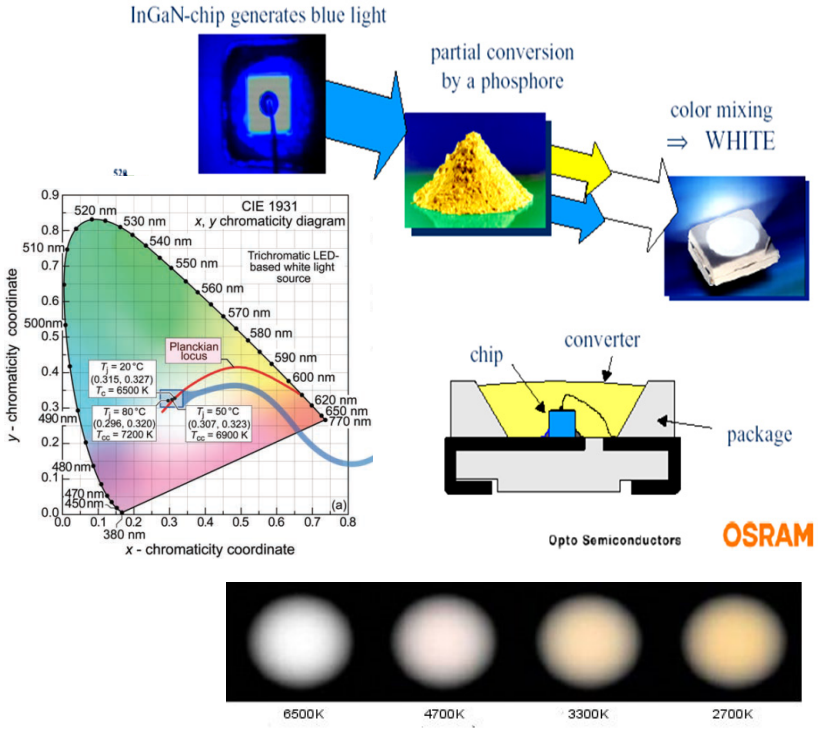
LED light bulb

GaN is the building block of solid state lighting (2nd most important semiconductor family after silicon)

Luminous efficiency

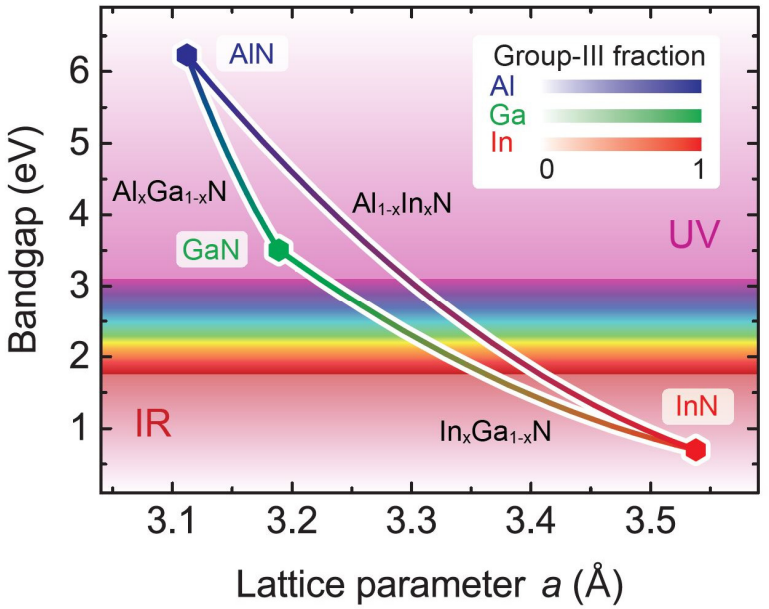
200 lm/W

Incandescent ×12
Fluorescent ×2.5



Physics of III-nitride semiconductors

- ✓ Wide bandgap (~3.4 eV for GaN)
- ✓ Mechanical hardness
- ✓ Optoelectronics
- ✓ Industrial production
- ✓ Biocompatibility
- ✓ Single photon emission at 300 K

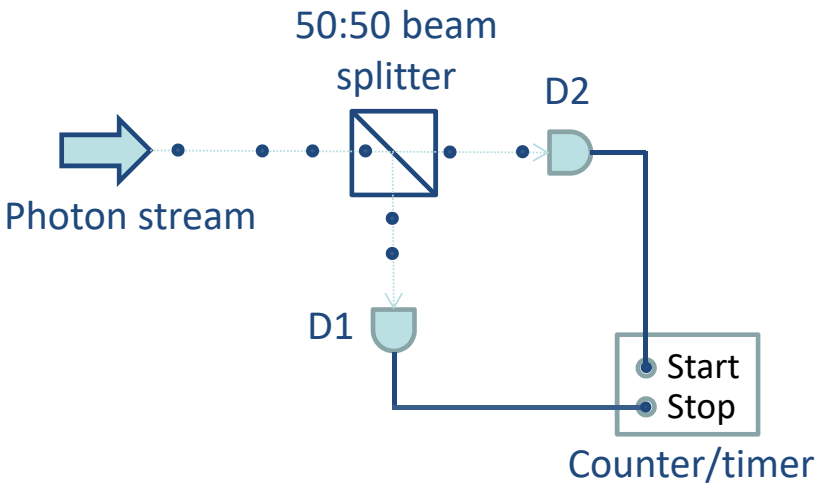


Interdisciplinary Physics

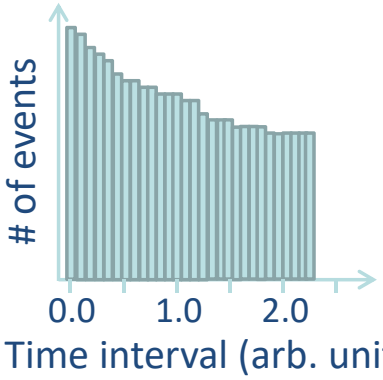
- Condensed matter physics
- Statistical physics applied to semiconductors
- Physics of quantum nanostructures (quantum wells, quantum dots)
- Quantum optics (single photon emitters, nanolasers)
- Light-matter interaction (photonic crystals, optical spectroscopy)

Characterization of single photon emitters (SPEs)

Hanbury Brown-Twiss experiment

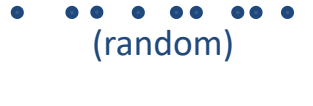


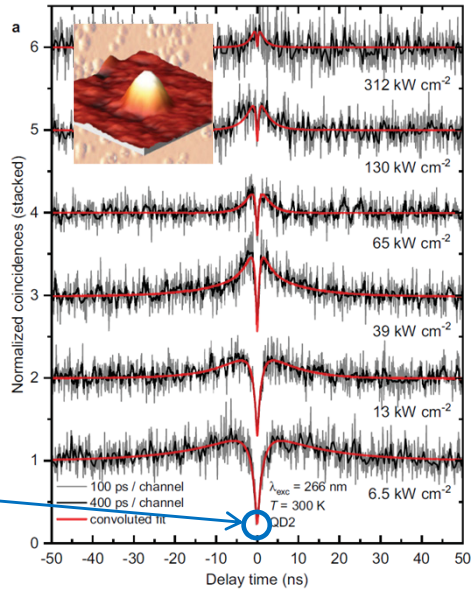
Histogram



Access to 2nd-order correlation function, $g^{(2)}(\tau)$, i.e., intensity fluctuations

- Bunched (chaotic) light: $g^{(2)}(0) > 1$
  Thermal light
- Coherent light: $g^{(2)}(0) = 1$
  Laser light
- Antibunched light: $g^{(2)}(0) < 1$
  SPEs

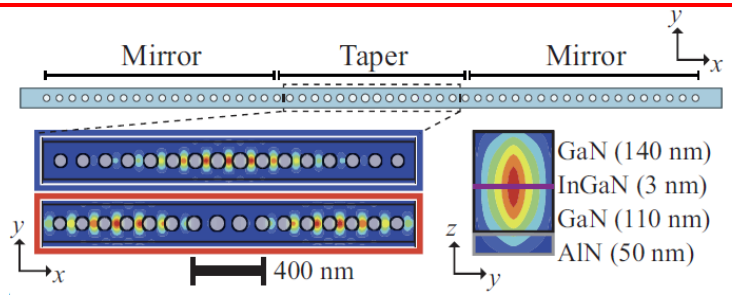




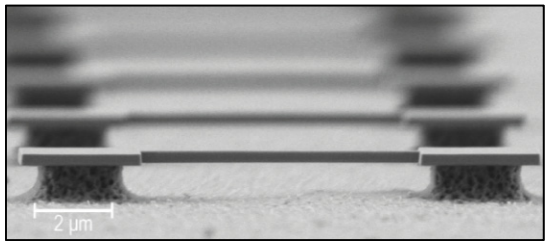
1 TP4 position

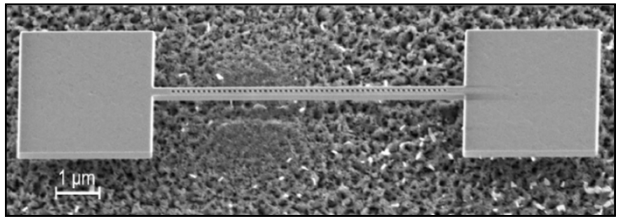
ACS Photonics **7**, 1515 (2020)

1D nanobeam photonic crystals



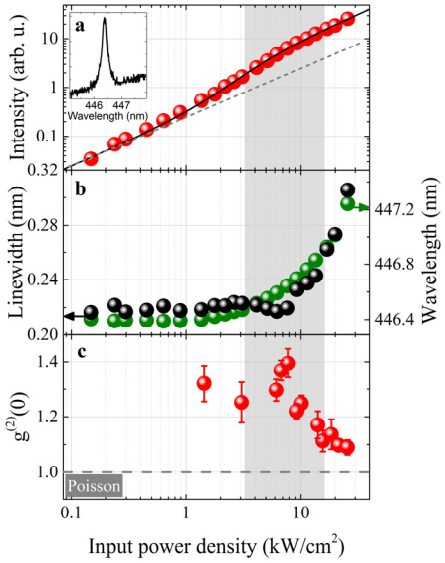
1D nanobeams behave as efficient nanolasers





- Clear threshold ✗
- Linewidth narrowing ✗
- Far-field pattern ✗

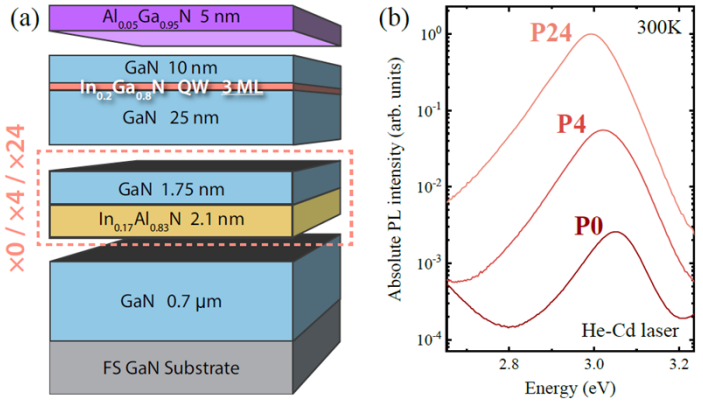
⇒ ***Need for an extra proof of lasing***

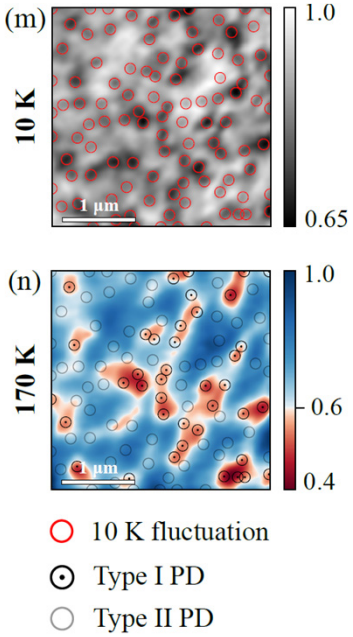


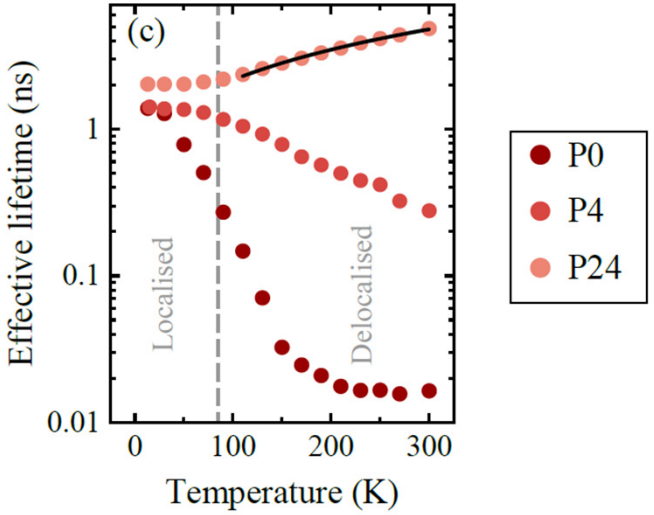
1 TP4 position

Nature Communications ***9****, 564 (2018)*

Physics of point defects: impact on light-emitters







$$IQE = \frac{\tau_{eff}}{\tau_{rad}}$$

Pending questions

- What is the atomic configuration of point defects (PDs)?
- What is their density?
- How can we decrease the incorporation of type II PDs?

2 TP4 positions

Appl. Phys. Lett. ***111***, 262101 (2017)
Appl. Phys. Lett. ***113***, 111106 (2018)
Appl. Phys. Lett. ***116***, 222106 (2020)
Appl. Phys. Lett. ***118***, 111102 (2021)
Nano Lett. (submitted)

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