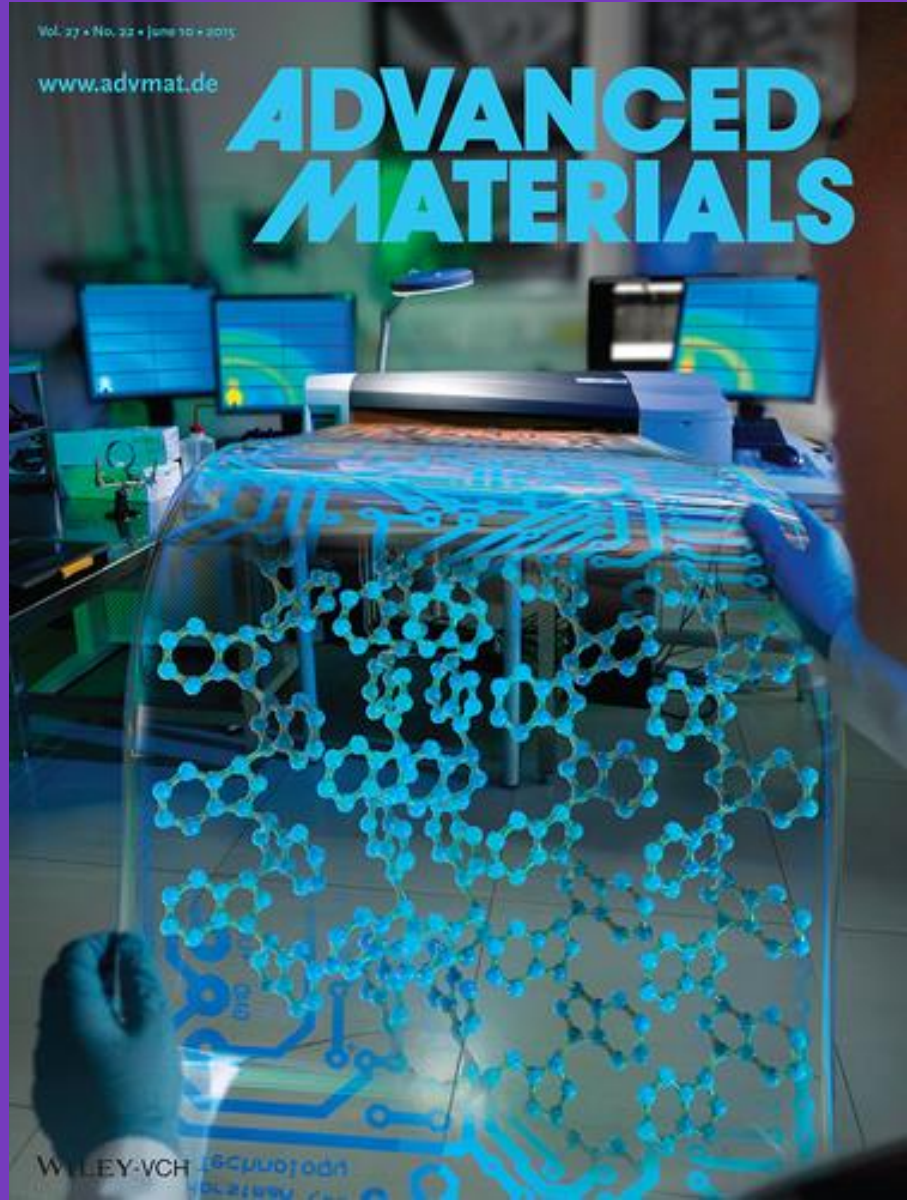
ELEC-E9210 Organic Electronics: Materials, Devices & Applications

Organic Light Emitting Transistors II

Aalto University
School of Electrical
Engineering

https://organicelectronics.aalto.fi

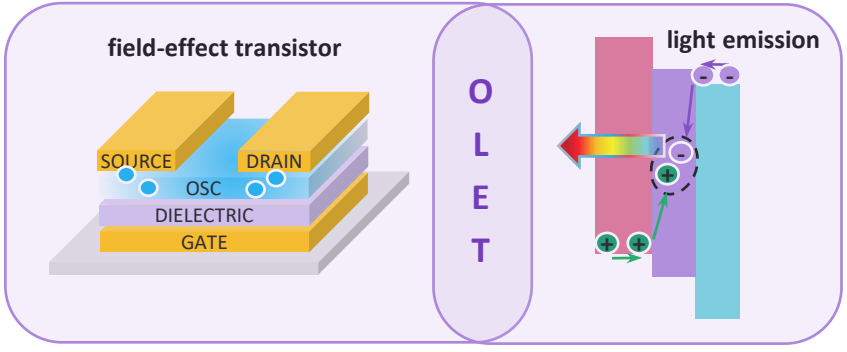


Organic Light Emitting Transistors (OLETs)

Previously…

Organic Light Emitting Transistor:

- charge transport and different regime
- Structures and properties

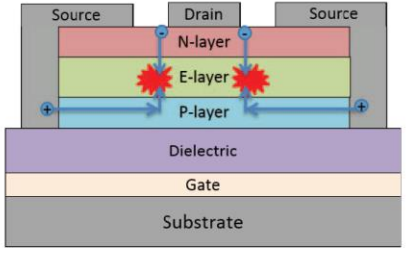


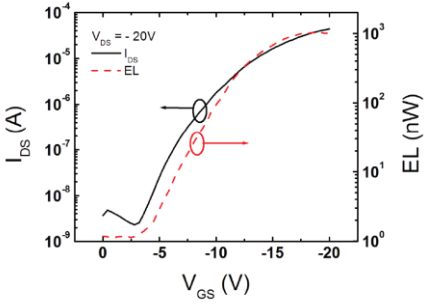
Today Class

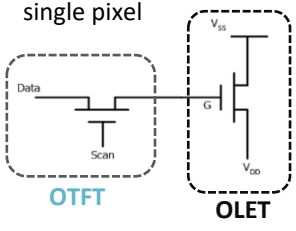
- **Applications** and **potentials** of organic light emitting transistors

Active-Matrix OLET (AM-OLET) Display

OLET-based technology platform potentially enables applications in several fields of ***flexible*** and ***wearable electronics***.

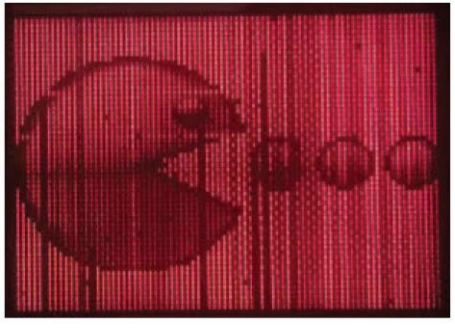


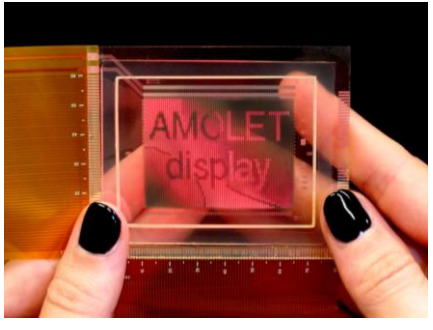




saes group ETC a SAES Group company

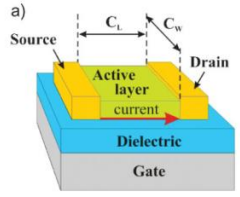
AMOLET display presented at SID2016



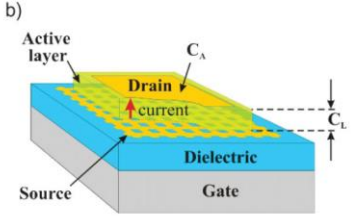


SID Symp. Dig. of Tech. Papers **47**(1), 739 (2016)

Vertical Organic Light Emitting Transistor (V-OLET)



$I_D \sim W/L$

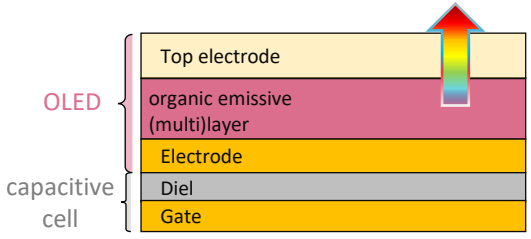


$I_D \sim$ area C_A
(overlap between S&D)

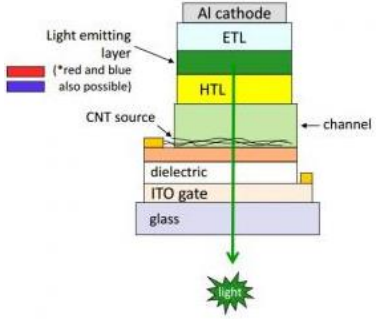
nanoscale channel length

- high current density
- high speed
- low operation voltage
- low power consumption

Vertical OLETs (V-OLETs) are vertically stacked structure consisting of a ***capacitor*** and an ***OLED*** (with one electrode in common)

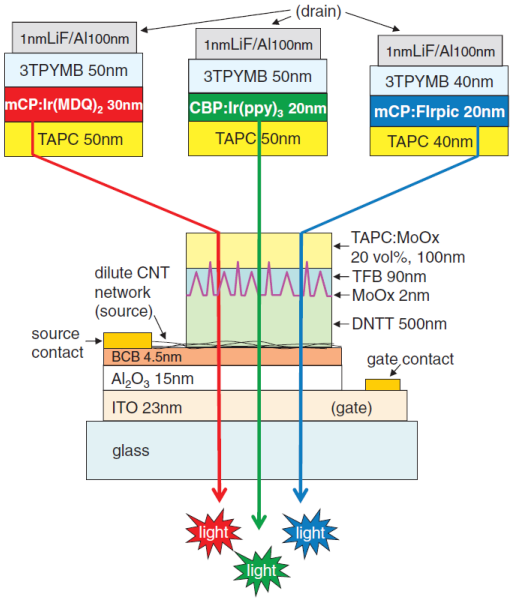


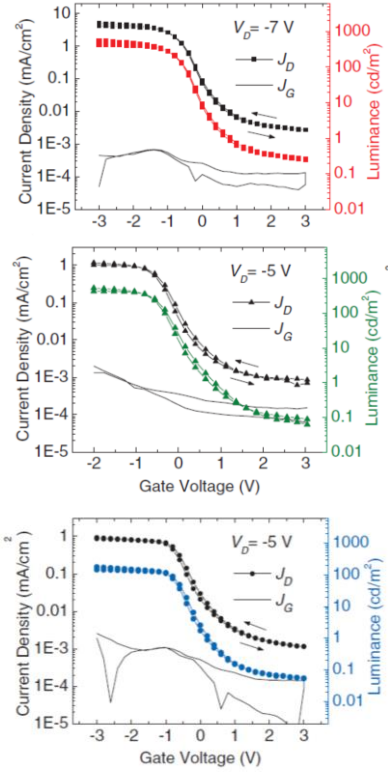
less space required for driving transistors (vertical integration)

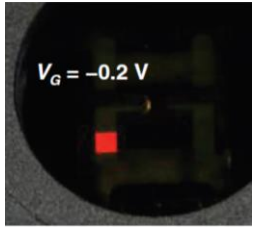


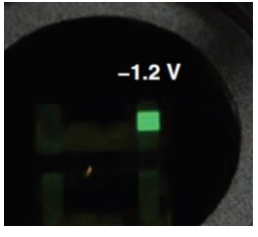
NOTE
Strictly speaking this is ***not a transistor*** in the classical sense (planar electrode, field-effect transport)

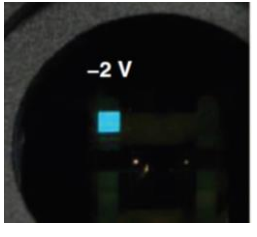
Vertical Organic Light Emitting Transistors (III)

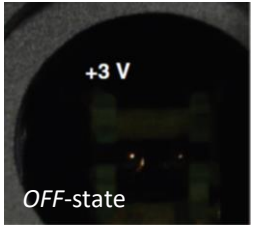








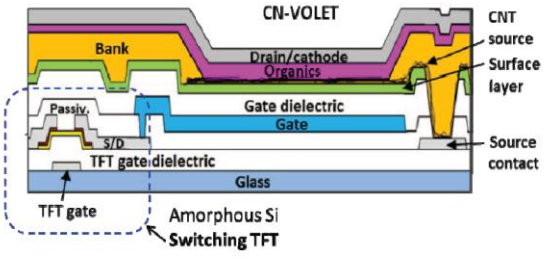


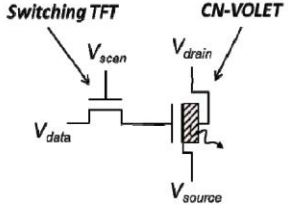


CNT-VOLET device transfer curve for R, G and B OLET with (right) corresponding optical images (emission area 14mm), with last image representing the *OFF*-state

Science **332**, 570 (2011)

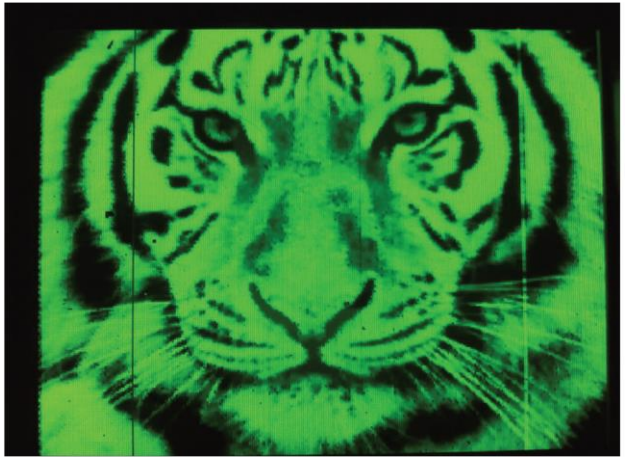
(Vertical) Active-Matrix OLET (AM-OLET) Display





Cross section of QVGA AMOLET pixel with CNT-VOLET and single switching TFT. Single pixel includes driving TFT, storage capacitor and OLED.

nVerpix

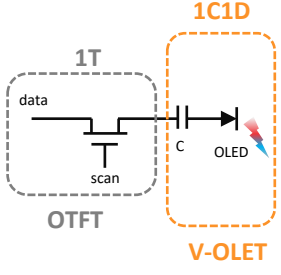


SID Symp. Dig. of Tech. Papers **47**(1), 1796(2016)

AMOLET display presented at SID2016

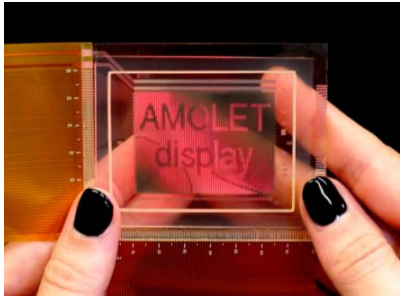
Comparison AM-OLET Display

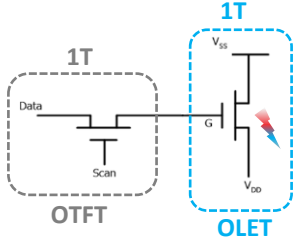
nVerpix



- higher resolution
- pin-hole issues (between S&D)
- *I*-driven (power consumption, heat management due to high current)

saes group ETC a SAES Group company





- spatial tuning of light
- *V*-driven
- simplified circuit

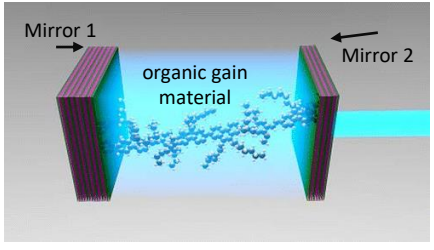
OLET: Potentials for Lasing

- ambipolarity (to mitigate losses)
- well-defined recombination zone
- high mobility* (→ high current densities)
- high EQE* (→ achieve net gain)

*(usually mutually exclusive in OM)

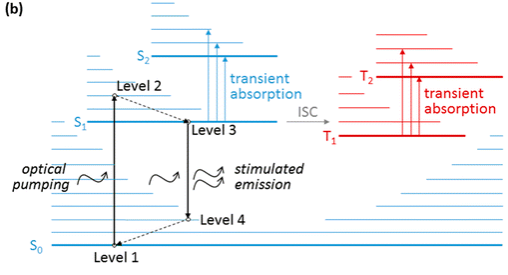
Lasing induced by electric field

Lasing concept



Chem. Rev. **116**, 12823 (2016)

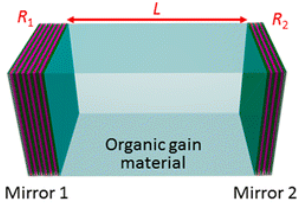
gain medium: organic luminophore, typically a π-conjugated aromatic hydrocarbon compound



feedback structure: often implemented through designing and structuring the organic materials

pump source: either *optical* (*i.e.* pulsed light source directed toward the organic gain material) or *electrical* (device)

OLET: Potentials for Lasing (II)



$$propagating\ electric\ field$$

$$E_0 = E_0\, e^{-i2lnk_0} \sqrt{R_1 R_2 e^{2L(g-\alpha)}}$$

$k_0=2\pi/\lambda_0$ — mirror reflectivity — optical gain — OM absorption @λ_0

condition for lasing
(capacity to retain light within the cavity)

$$g \geq \alpha - \frac{\ln R_1\, R_2}{2L}$$

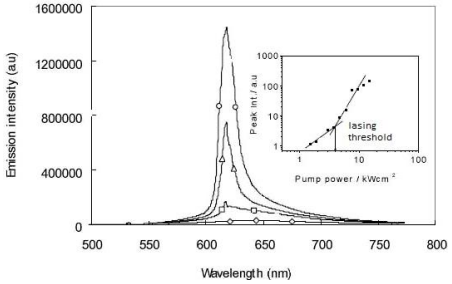
Amplified Spontaneous Emission (ASE)

Photons emitted by a luminophore through spontaneous fluorescence can be amplified (by stimulated emission) through interaction with other excited luminophores in the gain material.

→ trigger an avalanche of photons (ASE)

ASE is similar to laser emission

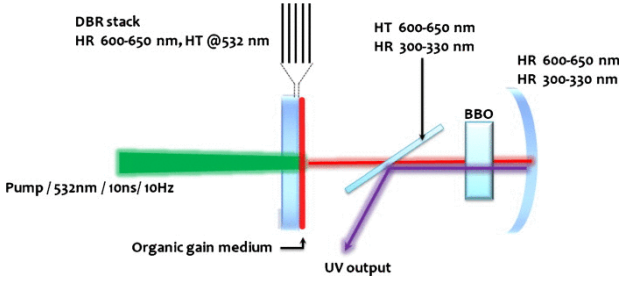
- ***spectral line width*** of the emission is generally ***narrower*** compared to the spontaneous fluorescence spectrum
- ***threshold behavior*** (*i.e.* the intensity of emission increases more rapidly beyond a certain threshold pump)

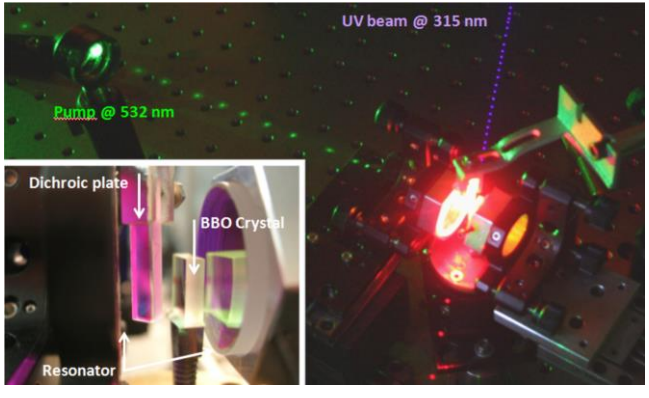


ASE spectrum of optically-pumped DCM2 laser. (Inset) Emission peak intensity as function of the pumped power density

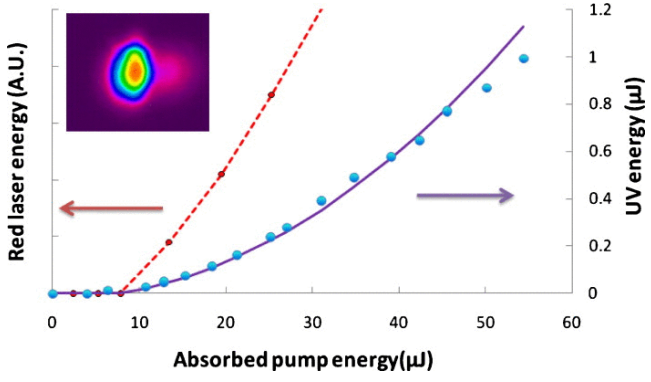
Optics Express **14**(20), 9436 (2006)

Potentials for Optically-*induced* Lasing





Appl. Phys. Lett. **98**, 131102 (2011)

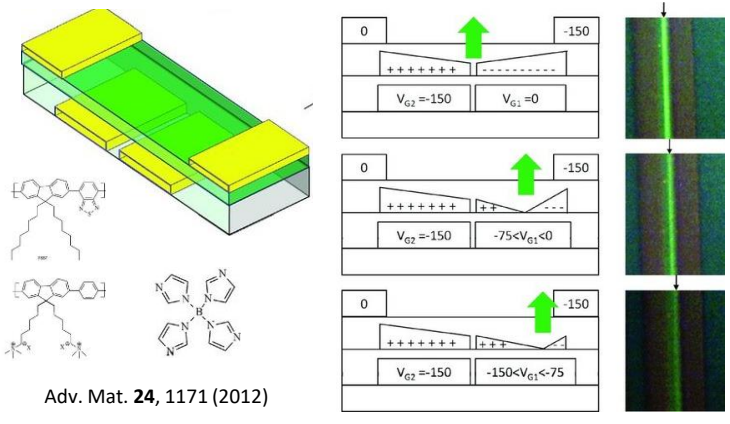


Schematic and photograph of a configuration with frequency doubling intra-cavity optics for generation of UV light.
Input-output characteristics for fundamental red and frequency doubled UV emission from laser, with beam profile of UV beam shown as inset.

Potentials for Electrically-*induced* Lasing

Controlling holes and electrons charge currents independently

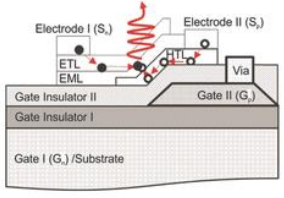
split-gate



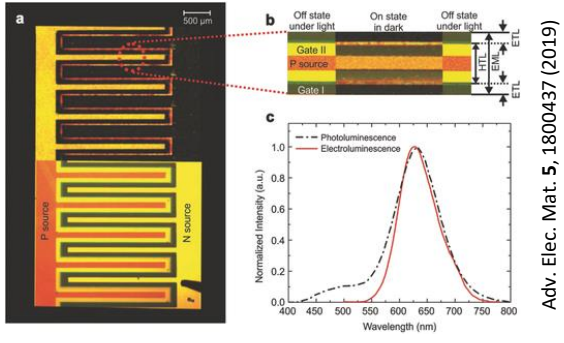
Adv. Mat. **24**, 1171 (2012)

Split-gate architecture allows for separate control of the two charge carrier distribution in the device, thus **high EQE** and greater **control over the recombination zone**

overlapping split-gate



Overlapping split-gate architecture allows for generation of matching hole and electrons currents in the emissive layer, which leads to **high EQE**

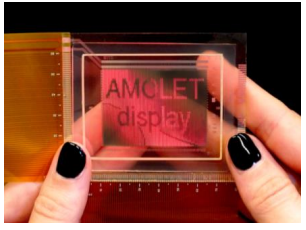


Adv. Elec. Mat. **5**, 1800437 (2019)

Summary

Today´s Class

- Organic light emitting transistors: organic transistor capable of emitting light
- Applications and potentials of OLET



Next Class

- Organic photovoltaics (OPV): basic mechanisms, materials and device structure
- OPV applications