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# Highly Luminescent YAP Thin Films as Nanoscale Optical Source for Ultra-High Resolution Microscopy

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## 1. Introduction

Far-field, as well as near-field approaches of super-resolution microscopy prospered in recent years. However, despite of variety techniques demonstrated nanoscale resolution, none of them are capable for imaging without dyes or label-free.

We have proposed an electron-beam excitation-assisted (EXA) optical microscope [1], where invasive character of electron irradiation vanished by luminescent film, producing noninvasive optical excitation for high resolution imaging of living cells.

## 2. YAP films as the nanoscale optical source

EXA microscope consists of inverted scanning electron microscope (SEM) and fluorescent microscope. Electron beam focused on luminescent film into a spot of few nm in diameter excites the nanoscale cathodoluminescence (CL).

We have fabricated thin scintillating films of gadolinium-doped yttrium aluminum perovskite (YAP) that act as a bright nanoscale optical source. Excited by a focused electron beam, YAP film emits tiny CL spot (Fig. 1 inset). This optical spot of a few tens nm in diameter generated in YAP thin film in near-field regime. Subsequent rastering over the film with a SEM gives a reconstructive image of the specimen with an ultra-high resolution.

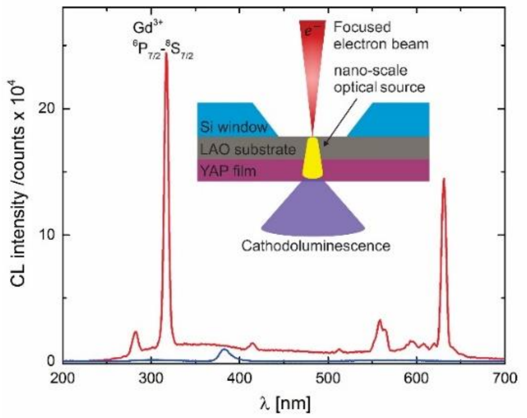


Fig. 1. CL spectra of $YAlO_3:Gd^{3+}$ film. Inset shows focused electron beam inside the Si window and CL irradiation from the YAP film.

Near-field approach involves the illumination, as well as the distance between optical source and the sample are smaller than the excitation wavelength. The CL light from YAP thin film is scattered in the specimen, collected and detected with a high sensitive photodetector. The near-field illumination makes it possible to achieve ultra-high resolution up to few tens of nanometers.

Because the specimen is located directly on thin film, the surface must be smooth, homogeneous and must emit persistent CL. Figure 2a shows CL image, taken inside the 100 μm window at the λ = 317 nm. Based on the acquired image and the intensity heatmap (Fig. 2c), CL intensity distribution of the YAP film is uniform with a 1.5% deviation, which indicates by normal distribution on Figure 2d.

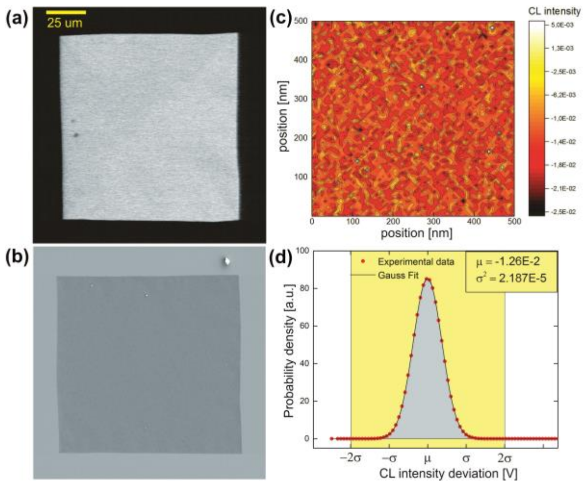


Fig. 2. (a) CL image. (b) SEM image of YAP film in the 100 μm window area. (c) Intensity heatmap of CL variability. (d) Normal distribution of CL intensity.

## 3. Conclusions

$YAlO_3:Gd^{3+}/LaAlO_3$ thin films on $Si/Si_3N_4/Y_2O_3$ substrates have been fabricated by radio-frequency magnetron sputtering. We report superior bright and homogeneous ultraviolet (UV) emission with a peak wavelength at 317 nm. CL spectra is characterized by a sharp, intensive peak attributed to $Gd^{3+}$ $^6P_{7/2}$-$^8S_{7/2}$ transitions [3]. YAP film is bright, sharp and spectrally selective nanoscale optical source with scintillator properties, which overcome previously reported results [1-2].

It is very promising as illuminating source for super-resolution microscopy, such as integrated light-electron microscope in which an inverted high-NA objective lens is positioned inside a SEM (Zonneville *et al.*); in EXA microscope for biological research and future single molecule detection; and as a free-standing membrane in bionanoreactor for dynamic nanoimaging (Nalan Liv *et al.*).

## References

[1] W. Inami, Optics express, Vol. 18, No. 12, 897-12 902, (2010).
[2] M. Fukuta, J. Biophotonics 1-8, (2016).
[3] E.J. Bosze, G.A. 104, 47-54 (2003). 252, pp 58-70 (2013).