Plasmon-enhanced Upconverting Nanoparticles: A Comparison of Analog and Digital Readout

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Abstract. Upconverting nanoparticles (UCNPs) have great potential for ultrasensitive biosensing due to their background-free detection enabled by the upconversion process, in which multiple low-energy photons are absorbed and converted into higher-energy emission. However, the main limitation of UCNPs is their low upconversion efficiency. One strategy to improve the upconversion luminescence is to use plasmon-enhanced techniques. There are two major challenges of plasmon-enhanced UCNPs: inhomogeneous plasmonic fields and plasmon coupling efficiency variations. Therefore, a systematic comparison between analog and digital readout is required to provide guidance for the design of robust and ultrasensitive biosensors based on plasmon-enhanced UCNPs.

Upconverting nanoparticles (UCNPs) have unique optical properties for biosensing: background-free detection, sharp emission lines, non-photobleaching, non-blinking and high stability [1,2]. Therefore, they have been used in highly sensitive biosensing applications [1–4]. UCNPs can be detected by either analog readout or digital readout. In analog detection, the upconversion luminescence (UCL) signal is integrated within the detection area, whereas digital detection quantifies discrete UCNPs by counting individual emitters.

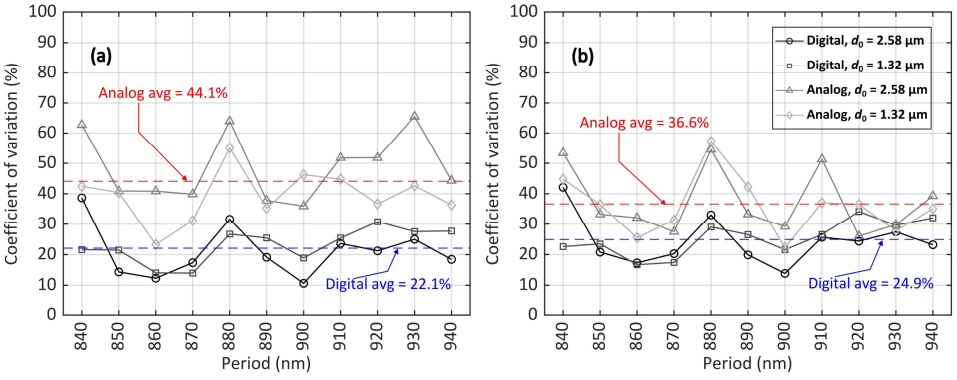

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Fig. 1. Coefficient of variation of 10 grating elements within each period in digital and analog detection of UCNPs with the 2.58 μm and 1.32 μm spots: (a) UCNP clusters included; (b) UCNP clusters excluded[5].

The main limitation of UCNPs is their intrinsically low upconversion efficiency[4,6]. Although plasmon-enhanced UCNPs can improve upconversion luminescence, they face two major challenges: inhomogeneous plasmonic fields and variations in plasmon coupling efficiency. Therefore, for plasmon-enhanced UCNPs, there is a need for a systematic comparison between analog and digital detection approaches. In this work, we compare analog and digital detection of plasmon-enhanced UCNPs mediated by surface plasmon polaritons (SPPs). A plasmon grating coupler matrix (varying period and fabrication tolerances) to vary SPP coupling efficiency was fabricated. UCNPs immobilized on the matrix were excited by diverging SPPs with two focused spot sizes (2.58 μm and 1.32 μm). SPP coupling efficiencies were calculated by COMSOL simulations. UCNPs were imaged with an EMCCD camera for analog and digital analysis. We found that analog detection strongly depended on the SPP coupling efficiency, whereas digital detection was largely independent of it. Moreover, analog detection exhibited higher variability than digital detection of UCNPs, as shown in Figure 1. These findings provide guidance for the design of robust and highly sensitive biosensors based on plasmon-enhanced UCNPs.

References

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