# Plasmon nanofocusing vs plasmon resonance: Which generates the strongest near-field light?

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## 1. Introduction

Strongly localized and enhanced near-field light generated near plasmonic nanostructures has been widely applied in various fields from material science to biology. The near-field light is often generated by localized plasmon resonance of metallic nanostructures such as a gold nanoparticle and nanorod. Recently, plasmon nanofocusing has also attracted much attention as another method to generate the near-field light due to its distinctive advantages such as background-free from incident light [1]. The near-field light is generated at an apex of a plasmonic tapered structure, such as a gold cone, through plasmons propagating toward the apex. Considering both methods of localized plasmon resonance and plasmon nanofocusing, one of pivotal questions is "Which generates more intense near-field light?", as the near-field light intensity is a fundamental and important property for most of optical applications.

## 2. Results and discussion

In this study, we numerically investigated which of localized plasmon resonance and plasmon nanofocusing generates intense near-field light. To evaluate the maximum near-field light intensities for both methods, we considered not only light field intensity but also heat generation and temperature in plasmonic structures. The near-field light intensity can be simply increased by increasing the incident light intensity. However, it is limited by the fact that too strong incident light destroys plasmonic structures as temperature goes beyond the melting point. Therefore, we calculated both electric field and temperature around the plasmonic structures using finite element method.

Figure 1(a) shows the calculation models for the localized plasmon resonance and plasmon nanofocusing. We chose 785 nm as the incident light wavelength. We used a gold nanorod and cone for the localized plasmon resonance and plasmon nanofocusing, respectively, as typical structures. Their geometries were optimized for the wavelength of 785 nm. We used a grating as a plasmon coupler for plasmon nanofocusing, which was located 3.75 µm far from the apex. Under incident light irradiation to the gold nanorod and the grating of the gold cone, we simulated the distributions of both the electric field and temperature, as shown in Figs. 1 (b, c). We confirmed that near-field light was generated for both cases. At the same time, we found that temperature of the structures increased due to heat generation. We further increased incident light intensity until temperature reaches the melting point of gold (1337K). In this situation, we found that the maximum near-field light intensity by plasmon resonance was $6.26 \times 10^{13}$ $V^2/m^2$. As for plasmon nanofocusing with the gold cone, the maximum near-field light intensity was $11.40 \times 10^{13}$ $V^2/m^2$. Therefore, we concluded that plasmon nanofocusing is capable of creating approximately twice stronger near-field light compared with localized plasmon resonance.

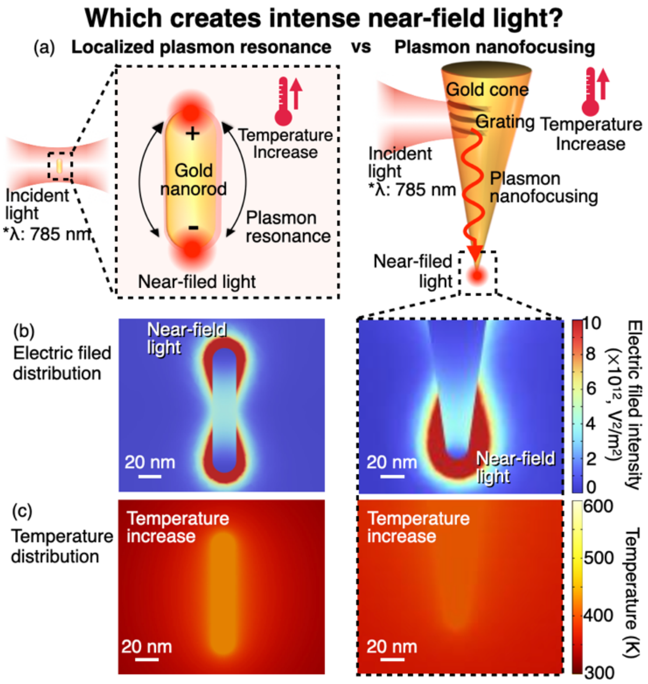


**Figure 1** Fig 1. (a) Schematics of calculation modes of (b) Electric field and (c) temperature distributions of the gold nanorod and cone.

## 3. Conclusions

In conclusion, we found that plasmon nanofocusing generates twice more intense near-field light compared with localized plasmon resonance. However, it was investigated only at a particular condition, which calls more extensive studies at various conditions in the future. In the presentation, we also discuss the case of more moderate temperature. Also, an interesting phenomenon of the near-field light intensity decrease with respect to the incident light intensity will be discussed.

## References

[1] T. Umakoshi, et al., *Sci. Adv.* **6**, eaba4197 (2020)