Intelligent Nanophotonic Architecture

Makoto Naruse[1,a,*], Masashi Aono[2,3], Song-Ju Kim[4]

[1] *Photonic Network Research Institute, National Institute of Information and Communications Technology, Tokyo 184-8795, Japan*

[2] *Earth-Life Science Institute, Tokyo Inst. Technology, Tokyo 152-8550, Japan*

3 PRESTO, Japan Science and Technology Agency, Saitama 332-0012, Japan

4 WPI Center for Materials Nanoarchitectonics, National Institute for Materials Science, Tsukuba 305-0044, Japan

[a]naruse@nict.go.jp

There is a great demand for novel intelligent devices and systems that can overcome the limitations of conventional technologies based solely on electron transfer, including the need to reduce energy consumption and solve computationally intractable problems. A promising solution is nanophotonics, which has been extensively studied with the aim of unveiling and exploiting light–matter interactions that occur at a scale below the wavelength of light. We consider that the unique attributes of nanophotonics can also be utilized in achieving novel *intelligent* capabilities [1-8]. We present three examples by exploiting near-field optical processes such as (1) energy transfer [1-6], (2) hierarchical properties [1,7], and (3) large momentum [8], what we can summarize as *intelligent nanophotonic architecture*.

Energy transfer: Optical near-field interactions between nanostructured matters, such as quantum dots, result in unidirectional optical excitation transfer when energy dissipation is induced. This results in versatile spatiotemporal dynamics of the optical excitation, which can be controlled by engineering the dissipation processes and exploited to realize intelligent capabilities such as solution searching [3] and decision making [4]. We recently experimentally demonstrate the ability to solve a decision making problem on the basis of optical excitation transfer by using colloidal quantum dots of different sizes formed on a geometry-controlled substrate [4,5]. Furthermore, *single-photon-based* decision making has been experimentally demonstrated through a collaboration with a Grenoble research team [6].

Hierarchy: An optical near-field behaves differently depending on the size of the physical scale involved [1]. By using such an attribute, tamper-resistant optical securities have been shown [1], and a physical unclonable function has recently been experimentally demonstrated [7].

Large momentum: The momentum of optical near-fields could be much larger than that of optical waves in free-space. Based on such nature, we theoretically demonstrate direction-dependent polarization conversion efficiency through a two-layer nanostructure mediated by optical near fields [8]. Such a principle provides unidirectional signal transfer and optical isolators, which are critically important in information and communications applications.

Acknowledgements: This work was supported in part by the Core-to-Core Program, A. Advanced Research Networks from the Japan Society for the Promotion of Science.

References:

[1] M. Naruse, N. Tate, M. Aono, and M. Ohtsu, Rep. Prog. Phys. **76**, 056401 (2013).
[2] M. Naruse, S.-J. Kim, M. Aono, H. Hori, and M. Ohtsu, Sci. Rep. **4**, 6039 (2014).
[3] M. Aono, *et al.*, Langmuir **29**, 7557-7564 (2013).
[4] S.-J. Kim, M. Naruse, M. Aono, M. Ohtsu, and M. Hara, Sci. Rep. **3**, 2370 (2013).
[5] M. Naruse, M. Aono, S.-J. Kim, *et al.*, J. Appl. Phys. **116**, 154303 (2014).
[6] M. Naruse, M. Berthel, A. Drezet, S. Huant, M. Aono, S.-J. Kim, *et al.*, submitted.
[7] T. Matsumoto, *et al.*, Sci. Rep. **4**, 6142 (2014).
[8] M. Naruse, A. Drezet, S. Huant *et al.*, J. Opt. Soc. Am B **31**, 2404-2413 (2014).