Spatiotemporal optical specification of quantum-dot network for optical reservoir computing

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Reservoir computing[1] is a type of recurrent neural network that can execute a computational task by utilizing fixed random weights of a network structure. Generally, such architecture is suitable for various applications that handle temporal data, such as speech recognition and dynamic prediction of stock prices. Recently, various concepts have been demonstrated experimentally by utilizing not only advanced electronics but also other physical technologies[2,3]. In this study, we propose the implementation of an optical reservoir based on a quantum dot (QD) network. The electronic state of each QD is excited by irradiation of light, and this energy is allowed to transfer to the surrounding QDs in the network. As a result, the energy transfer and corresponding emissions from the network are expected to exhibit spatiotemporal optical variations of nonlinear input-output relations, which is strongly required in the development of a physical reservoir. Furthermore, using nanometer-sized QDs, a miniaturized and lower energy-consumption reservoir is expected to be realized. Here, some experimental results are shown to demonstrate the energy transfer and corresponding spatiotemporal emissions of the QD network.

Figures 1(a) and (b) show the appearance and schematic of the sample, respectively. As shown, three types of QDs (Emission peak wavelengths λ_{em} = 540, 580, and 620 nm) were randomly dispersed in each polymer solution as individual QD networks, and each layer was stacked in an order such that it induces energy transfer between the different types of QDs. The sample was then irradiated by a pulsed laser (λ_{ex} = 515 nm), and the emission results were obtained using a spectrometer and a single-photon detector. The size of each observation area was considerably lower than the 10-μm square. As shown in Fig. 1(c), the emission spectra obtained at different areas show different spectra referred to as the spatial variation of the QD network. Furthermore, as shown in Fig. 1(d), emission at λ = 538 nm from each area shows different decay rates, which corresponds to delay of energy transfer in each QD network, referred to as the temporal variation of the QD network.

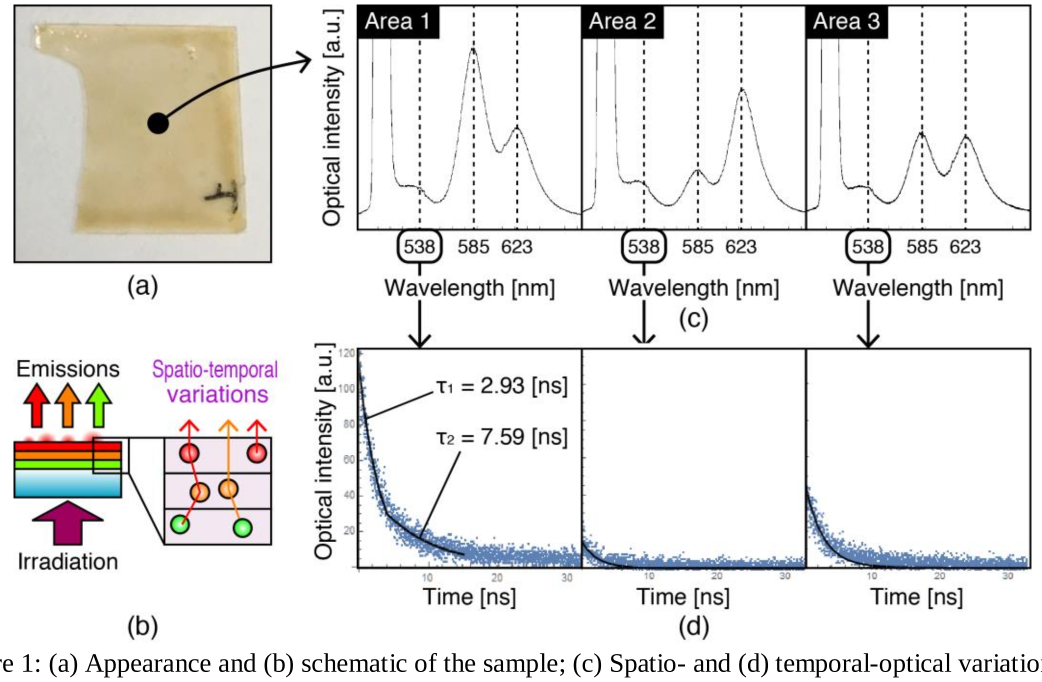

Figure 1: (a) Appearance and (b) schematic of the sample; (c) Spatio- and (d) temporal-optical variation of the sample.

In this study, we proposed a QD network as a key component of an optical reservoir. The experimental results using the QD network exhibit spatiotemporal variations of input–output relations, which is due to nanoscale energy transfer. In a future study, we would discuss a method for the enhancement of spatiotemporal variation of the QD network, and verify its superiority in advanced reservoir computing.

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References

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