# Random Laser From Reconfigurable Active Controlled Colloids

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Random lasing, where multiple scattering of light drives amplification in disordered media, has been observed in many architectures, such as cavity-with-holes [1], optofluidic microchannels [2] and photonic glass [3]. However, they cannot be reconfigured post fabrication, and are therefore static in nature. Here, we demonstrate the dynamic self-assembly of colloids into an active random laser that can be modified in real-time via the control of a laser beam.

A colloidal suspension (sandwiched between two glass slides, 20 $\mu$m apart) consists of randomly distributed 1.6 $\mu$m-diameter titania ($TiO_2$) particles and 8 $\mu$m-diameter carbon-coated silica particles in a Rhodamine B-doped ethanol solution. The $TiO_2$ particles provide scattering to the system and determine the scattering mean free path by the particle density. Here, the silica beads with carbon coated on one side are utilised as the seeds for the formation of random lasers. By creating a temperature gradient through the heating from the focused HeNe laser on the carbon-coated silica bead, the motion of the $TiO_2$ particles is activated by the Marangoni effect [4]. In this case, the colloids are attracted to the bead and a cluster can be constructed by simply heating the silica bead locally, as illustrated in Figure 1a. The cluster region forms a significantly denser area compared to the environment. In other words, scattering events occur much more frequently in this local area, resulting in a favourable building block for random lasers.

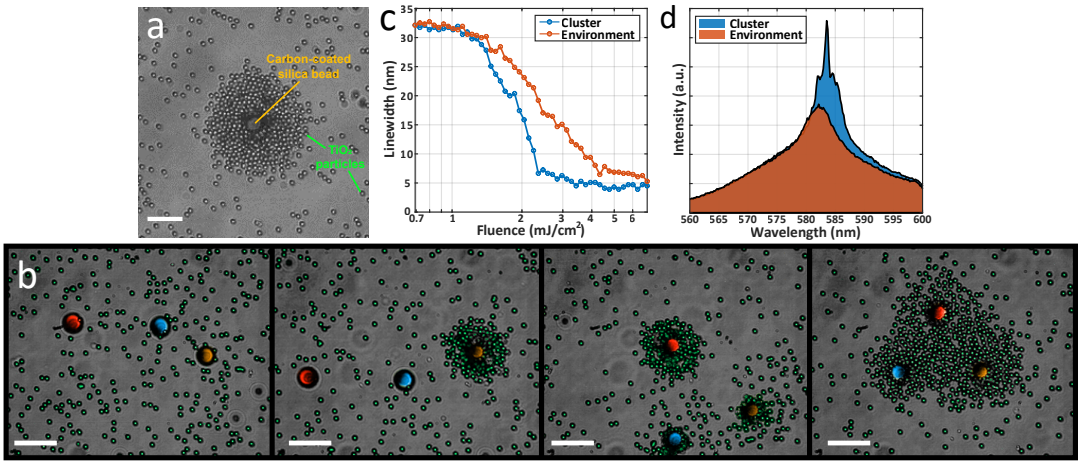


Figure 1: (a) A single cluster composed of titania particles with a carbon-coated silica bead located at the centre. (b) The accumulation process (from left to right) showing the formation of the triangular random laser through active controls. The carbon-coated silica beads are painted with different pseudo-colors for identification and for better visualisation. The scale bars in (a) and (b) represent 20 $\mu$m. (c) The evolution of linewidths as a function of pump fluence and (d) the emission spectra at a fluence of 2.77 mJ/cm$^2$, for both the random laser cluster and the surrounding environment. The narrowing of the spectrum from the cluster demonstrates a lasing action with a lower threshold.

Apart from attraction to the $TiO_2$ particles, the asymmetric carbon coating on the silica bead also creates self-propulsion under laser heating [5]. This enables us to move and control the formation of particle clusters at the desired locations. The design of random laser architecture is crucial as it determines the spatial distribution of the modes, hence changing the lasing actions. A simple demonstration of the construction process of a triangular-shaped random laser is shown in Figure 1b. The silica beads are first guided to the three corners of a desired random laser location, and individual particle islands are also formed surrounding the beads in the meantime. After gathering enough particles for the islands, the positions of the beads are adjusted to merge them into a large triangular cluster. We have characterised the lasing action from this triangular random laser, as well as compared it with the environment, in Figures 1c and d. A narrow peak (FWHM $\approx$ 7 nm) indicates the random lasing phenomenon from the cluster, whereas the environment with much broader emission does not show random lasing under the same pumping fluence. Since the particles are free-floating in the solution, reconfiguring the random laser is possible by simply moving the carbon-coated silica bead and reaccumulating the cluster at other positions. Our study demonstrated an actively controlled random laser by using self-assembled colloids. This on-site real-time reconfigurable random laser has the potential to be applied to other fields, such as living matter materials and bioengineering.

## References

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