Triplet recycling for quasi-continuous-wave organic semiconductor lasers

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Organic semiconductor lasers are well known for its excellent performance in short-pulse photoexcitation. However, lasing under continuous-wave or long-pulse photoexcitation from organic semiconductors is challenging because of the accumulation of long-lived triplets which formed *via* intersystem crossing from radiative singlets. Subsequently, these triplets induce singlet-triplet annihilation (STA), resulting in low singlet density in a laser medium. Hence, lasing from organics stops immediately. So far to induce organic lasing under long-pulse photoexcitation, these detrimental triplets should be eliminated from the laser medium. Instead of eliminating the long-lived triplets, here we report an efficient recycle of these triplets *via* triplet scavenging and then triplet up-conversion using triplet-triplet annihilation (TTA) to generate more singlet excitons in the laser medium. An anthracene derivative of 9-(1-naphthalenyl)-10-(4-(2-naphthalenyl)phenyl)anthracene (NaNaP-A) and a laser dye of 4,4’-bis[4-(diphenylamino)styryl]biphenyl (BDAVBi) were used as the triplet recycling host and laser dye in our laser system. BDAVBi has a considerable overlap of its emission spectrum with a triplet absorption spectrum of NaNaP-A which normally induces strong STA. However, a deep triplet state (1.5 eV) of NaNaP-A scavenges the long-lived triplets formed on BDAVBi *via* intersystem crossing and its long triplet lifetime (369 μs) facilitates TTA to upconvert the scavenged triplets into the singlets. As the STA process is suppressed with the triplet recycling process, our laser system could operate under long-pulse photoexcitation of up to 10 ms. Finally, the triplet recycling mechanism was further confirmed by transient electroluminescence and photoluminescence.

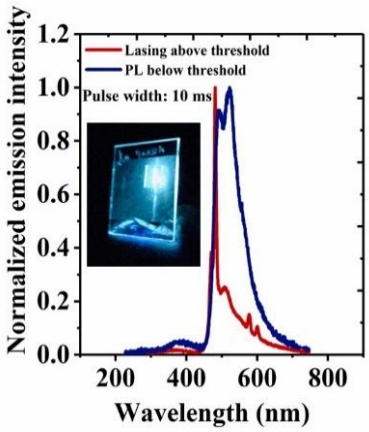

Figure 1. Laser emission under 10 ms pulse photoexcitation below (blue) and above (red) lasing threshold. Inset shows a photo of the lasing under long-pulse operation.