Boron quantum dots all-optical modulator based on efficient photothermal effect

Cong Wang$^1$†, Qianyuan Chen$^2$†, Hualong Chen$^1$, Jun Liu$^1$, Yufeng Song$^1$, Jie Liu$^3$, Delong Li$^1$, Yanqi Ge$^1$, Youning Gong$^1$*, Yupeng Zhang$^1$* and Han Zhang$^1$

$^1$Collaborative Innovation Center for Optoelectronic Science & Technology, International Collaborative Laboratory of 2D Materials for Optoelectronics Science and Technology of Ministry of Education, Institute of Microscale Optoelectronics, Shenzhen University, Shenzhen 518060, China; $^2$School of Physics and Technology, and MOE Key Laboratory of Artificial Micro-and Nano-Structures, Wuhan University, Wuhan 430072, China; $^3$Shandong Provincial Engineering and Technical Center of Light Manipulation & Shandong Provincial Key Laboratory of Optics and Photonic Device, School of Physics and Electronics, Shandong Normal University, Jinan 250014, China.

†These authors contributed equally to this work.

*Correspondence: YN Gong, E-mail: youninggong@szu.edu.cn; YP Zhang, E-mail: ypzhang@szu.edu.cn

This file includes:

Section 1: Preparation of BQDs
Section 2: Determination of the absorption coefficient of BQDs dispersions
Section 3: Characterization

Supplementary information for this paper is available at https://doi.org/10.29026/oea.2021.200032
Section 1: Preparation of BQDs
In a typical procedure, 25 mg bulk boron powder was directly added into 50 ml dimethylformamide (DMF) solvent to form a suspension with the initial concentration of 0.5 mg/ml. The suspension was firstly sonicated by 700 W probe ultrasonication for 3 h at 5 °C, then centrifuged at 6000 rpm for 30 min to remove unexfoliated boron particles. Next, the obtained light brown dispersions in DMF were centrifuged at 15000 rpm for 1 h to concentrate the as-exfoliated boron sample. After that, the collected boron samples were further treated by high energy ball milling (Nanjing University Instrument Plant, QM-3SP2) with a rate of 500 rpm for 24 h. Finally, the resultant boron/DMF solution was centrifuged successively at 10000 rpm for 30 min and 13000 rpm for 60 min to obtain the final BQDs product.

Section 2: Determination of the absorption coefficient of BQDs dispersions
Typically, the as-prepared BQDs dispersion was further centrifuged at 15000 rpm for 1 h. The resultant solid product was collected, followed by drying under vacuum at 60 °C for 8 h. 3.5 mg of the solid BQDs product was then redispersed in 4 mL of deionized water (DIW) by 15 min sonication under a constant temperature of 10 °C. The obtained BQDs/DIW dispersion was used to determine the corresponding absorption spectra.

Section 3: Characterization
The morphology and microstructure of the samples were characterized via scanning electron microscope (SEM; Sirion, FEI, Netherlands), HRTEM (Tecnai G2 F30) and AFM (Dimension Edge, Bruker, America) equipped with an energy-dispersive X-ray spectrometer (EDS; Genesis 7000, EDAX Inc., USA). The elemental compositions were analyzed via X-ray photoelectron spectroscopy (XPS; AXIS-Ultra instrument, Kratos Analytical, England) with a monochromatic Al Kα X-ray beam (225 W, 15 Ma, 15 kV). The UV-Vis diffuse reflectance spectra (DRS) of the samples were measured with the diffuse reflectance accessory of UV-Vis spectrophotometer (UV-2550; Shimadzu, Kyoto, Japan), in which BaSO₄ was used as a background between 200–1200 scopes.

![Fig. S1](https://doi.org/10.29026/oea.2021.200032) | The work principle of pump probe setup. (a) The relationship between pump light and probe light in time domain and space domain. (b) The schematic diagram of pump probe setup.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Wavelength (nm)</th>
<th>τ₁ (fs)</th>
<th>τ₂ (ps)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BQDs</td>
<td>970</td>
<td>194</td>
<td>15.1</td>
<td>This work</td>
</tr>
<tr>
<td>Graphene</td>
<td>-</td>
<td>210</td>
<td>1.67</td>
<td>ref.¹</td>
</tr>
<tr>
<td>Cu₂₋ₓS</td>
<td>1300</td>
<td>315</td>
<td>34</td>
<td>ref.²</td>
</tr>
<tr>
<td>SnS</td>
<td>~1000</td>
<td>620</td>
<td>153</td>
<td>ref.³</td>
</tr>
<tr>
<td>WS₂</td>
<td>~564–689</td>
<td>1300</td>
<td>100</td>
<td>ref.⁴</td>
</tr>
<tr>
<td>Graphdiyne</td>
<td>~ 900</td>
<td>1400</td>
<td>24</td>
<td>ref.⁵</td>
</tr>
</tbody>
</table>

Table S1 | The relaxation time constants of current state-of-the-art materials.
References


