Stimulated Emission in Blue Wavelength Region from a Copolymer

1999 Chinese Phys. Lett. 16 455

(http://iopscience.iop.org/0256-307X/16/6/024)

Stimulated Emission in Blue Wavelength Region from a Copolymer *

LIU Xing-yuan(刘星元)[1,2], WANG Shu-mei(王淑梅)[3], FENG Ji-meng(冯纪蒙)[4], LIANG Chun-jun(梁春军)[1], ZHAO Dong-xu(赵东旭)[1], HONG Zi-ruo(洪自若)[1], LI Wen-lian(李文连)[1], PENG Jun-biao(彭俊彪)[3], YU Jia-qi(虞家琪)[3], ZHAO Jia-min(赵家民)[1], WANG Li-jun(王立军)[3], WANG Li-xiang(王利祥)[2], JING Xia-bin(景遐斌)[2], WANG Fo-song(王佛松)[2]

[1] *Changchun Institute of Physics, Chinese Academy of Sciences, Changchun 130021*

[2] *Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun 130022*

[3] *Laboratory of Excited State Processes, Chinese Academy of Sciences, Changchun 130021*

[4] *Changchun Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Changchun 130022*

(Received 9 November 1998)

A dye laser based on the soluble conjugated polymer, Poly[1,8-octanedioxy-2,6-dimethoxy-1,4-phenylene-1,2-ethenylene-1, 4-phenylene-1,2-ethenylene-3,5-dimethoxy-1,4-phenylene], has been fabricated. The laser was pumped by light pulses from the third harmonic radiation of an Nd:YAG laser. The lasing was observed in the blue wavelength region with the peak at 450 nm. The threshold energy is about 19 μJ. The energy conversion yield of the laser is about 3.4%. The maximum peak power of the laser output pulse arrives at about 20 kW.

PACS: 78. 60. Fi, 81. 20. Sh

Semiconducting conjugated polymers such as poly(p-phenylenevinylene) (PPV) and its derivatives are potential materials for applications in optoeletronic devices such as light-emitting diodes,[1-3] field-effect transistors[4] and solar cells.[5] Because of the relatively high photoluminescence (PL) quantum yield, conjugated polymers have stimulated the intensive research in the possibility of achieving polymer lasers. Moses reported for the first time a dye laser made from conjugated polymer (MEH-PPV) in 1992.[6] Its quantum yield is comparable to that of rhodamine 6G. Brouwer *et al.* studied the laser performance and wavelength tunability of TOP-PPV in solution.[7] The efficiency of this copolymer in hexane exceeds that of both coumarin dyes with more than 50%. More recently, polymer lasers in various forms have been demonstrated under optical excitation.[8-10]

It is known that there are some advantages of the polymer laser. The absorption coefficient of the polymer is large; the absorption and emission are spectrally separated due to Stokes shift, the self absorption is minimal, so the inverted population can be facilely achieved. Conjugated polymers can exhibit emission throughout whole visible spectrum through chemical modification. In this letter, we present a laser emission in the blue wavelength region from solution of a soluble PPV derivative-Poly[1, 8-octanedioxy-2, 6-dimethoxy-1, 4-phenylene-1, 2-ethenylene-1, 4-phenylene-1, 2-ethenylene-3, 5-dimethoxy-1, 4-phenylene] (CNMBC-Ph), which is a kind of copolymer that contains alternating conjugated and nonconjugated blocks. The copolymer shows a high PL quantum efficiency.[11-12] The chemical structrue of CNMBC-Ph and a schematic diagram of the polymer dye laser is shown in Fig. 1.

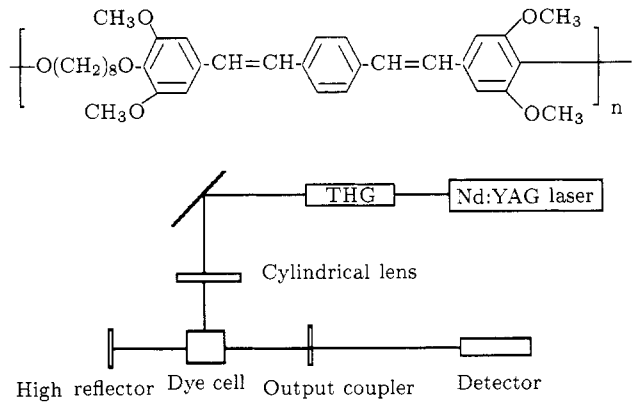

Fig. 1. Chemical structure of CNMBC-Ph and a schematic diagram of the polymer dye laser.

The sample solution was prepared as follows: CNMBC-Ph powder material was dissolved in chloroform with a concentration of 3 mg/ml. Then the solution was put into the dye cell with 1 cm^2 cross section. The resonator is composed of two flat mirrors. A flat Al mirror is used as the high reflector, and a polished flat quartz glass is used as the output coupling mirror. To avoid feedback from the walls of the dye cell, the cell was slightly tilted with respect to the cavity axis. The solution was transversely pumped by 300 ps pulses from the third harmonic radiation of an active mode-locked Nd:YAG laser, the excitation wavelength is 355 nm. The pumped beam was focused on the solution by a cylindrical lens to a 5×0.2 mm^2 area. The absorption spectrum was measured with Shimadzu dual-wavelength/double-beam

*Supported by the National Natural Science Foundation of China under Grant No. 79577018, the Key Project of Chinese Academy of Sciences for the Ninth Five-Year Plan, and the Hundreds of Talents Program in Chinese Academy of Sciences.

recording spectrophotometer UV-3000. The PL emission spectrum was measured with Hitachi spectrophotometer F4500. All measurements were performed in air at room temperature.

The absorption and PL emission spectra of CNMBC-Ph in chloroform are illustrated in Fig. 2. The absorption peak is located at 360 nm, so the excitation of the sample solution with 355 nm is efficient. The PL emission spectrum of CNMBC-Ph in chloroform is a broad emission band at blue region with a maximum peak at 464 nm. The full width at half maximum (FWHM) is about 80 nm.

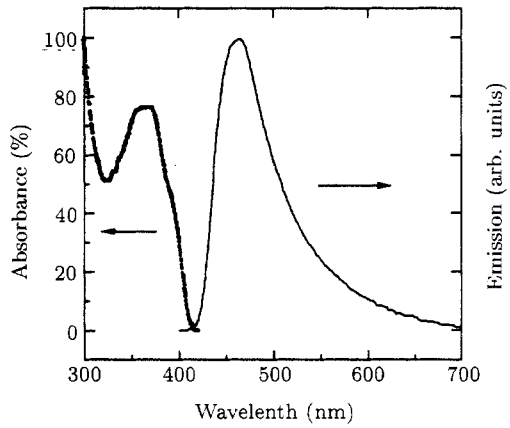

Fig. 2. UV absorption spectrum (dotted line) and PL emission spectrum (solid line) of CNMBC-Ph in chloroform.

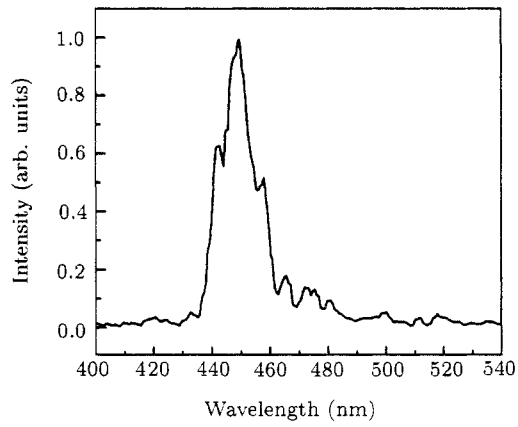

Fig. 3. Lasing spectrum of CNMBC-Ph in chloroform.

Figure 3 shows the lasing spectrum of CNMBC-Ph in chloroform. The measurement of the lasing spectrum was limited by the low resolution (2 nm) of the spectrometer used in this study. When the pump energy exceeds the threshold energy of the laser, the laser beam spot can be seen on a screen behind the output coupler. When blocking the high reflector of the cavity to interrupt the feedback system, the spot disappeared on the screen. The laser beam observed is a highly directional blue light. The divergence of the laser beam is about 2 mrad. Figure 3 illustrates that the lasing peak is located at 450 nm. The FWHM of the lasing spectrum is approximately 15 nm, which shows a wide spectrum gain.

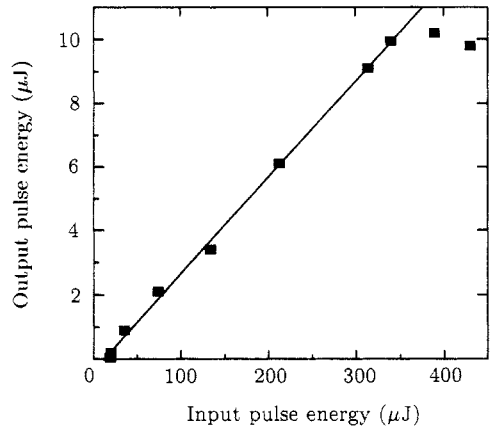

Fig. 4. Laser output pulse energy vs the pump pulse energy.

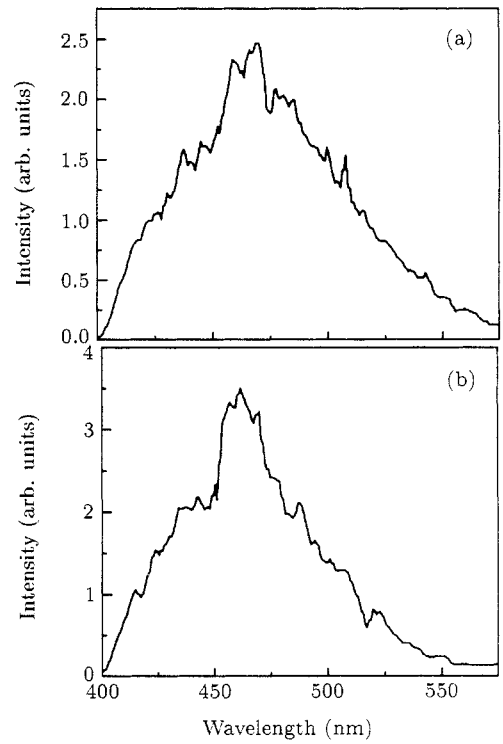

Fig. 5. Spontaneous emission spectrum of CNMBC-Ph in chloroform under 355 nm excitation at energy (a) 19μJ and (b) 40μJ.

Figure 4 depicts the laser output pulse energy as a function of the pump pulse energy. When the pump pulse energy is below 340 μJ, the output pulse energy increases nearly linearly to the pump pulse energy. The energy conversion efficiency of CNMBC-Ph in chloroform is about 3.4%. When the pump pulse energy exceeds 340 μJ, the laser output energy is saturated. The threshold energy of the lasing is approximately 19 μJ. The maximum output energy is about 10 μJ. The temporal profile of the laser pulses

was monitored with Streak Camera M1764. The measured fluorescence lifetime of CNMBC- Ph in chloroform is 1.1 ns. The pulse duration of the lasing output is about 500 ps. The maximum peak power of the output pulse arrives at about 20 kW.

The fluorescence emission spectrum was measured while the pumped light was incident on the same solution at a 45° angle when the two reflectors were removed. Figure 5 shows the emission spectrum pumped at 19 and 40 μJ, respectively. As the pump energy is increased, a collapse of the emission band at about 450 nm becomes obvious, which is with respect to the lasing peak shown in Fig. 3. It is assumed that the PL emission spectrum of CNMBC-Ph may be the combination of two emission bands. The lasing originates from the first vibration band.

In conclusion, we have shown the lasing property of CNMBC-Ph in chloroform solution. The stimulated emission can be observed in the blue spectral range under the excitation at 355 nm. The lasing emission spectrum shows a linewidth of 15 nm. The energy conversion efficiency of the laser is about 3.4%. The maximum peak power of the output pulse arrives at about 20 kW.

REFERENCES

[1] J. H. Burroughes, D. D. C. Bradley, A. R. Brown, R. N. Marks, K. Mackay, R. H. Friend, P. L. Burns and A. B. Holmes, Nature, 347 (1990) 539.

[2] CHEN Bai-jun, HOU Jing-ying, HUANG Jing-song and LIU Shi-yong, Chin. Phys. Lett. 14 (1997) 74.

[3] TAN Hai-shu, CHEN Li-chun, WANG Xiang-jun, YAO Jian-quan, JU Chuan-xi, XIE Hong-liang and GAO Guang-hua, Chin. Phys. Lett. 15 (1998) 137.

[4] J. H. Burroughes, C. A. Jones and R. H. Friend, Nature, 335 (1988) 137.

[5] N. S. Sariciftci, L. Smilowitz, A. J. Heeger and F. Wudl, Science, 258 (1992) 1474.

[6] D. Moses, Appl. Phys. Lett. 60 (1992) 3215.

[7] H. J. Brouwer, V. V. Krasnikov and A. Hilberer, Appl. Phys. Lett. 66 (1995) 3404.

[8] C. Zenz, W. Graupner, S. Tasch, G. Leising, K. Mullen, U. Scherf, Appl. Phys. Lett. 71 (1997) 2566.

[9] F. Hide, M. A. Diaz-Garcia, B. J. Schwarta, M. R. Andersson, Q. Pei and A. J. Heeger, Science, 273 (1996) 1833.

[10] V. G. Kozlov, V. Bulovic and S. R. Forrest, Appl. Phys. Lett. 71 (1997) 2575.

[11] Z. Yang, I. Sokolik and F. E. Karasz, Macromolecules, 26 (1993) 1188.

[12] B. Hu, Z. Yang and F. E. Karasz, J. Appl. Phys. 76 (1994) 2419.