White Paper
532, 561, 594 nm compact visible lasers
QD Laser, Inc.

1. Introduction

Demand for cell analyzers in the biomedical field such as flow cytometers and fluorescence microscopes has increased, and the instruments are becoming smaller with improved functionality. Since 561 and 594 nm laser light used in the instrument cannot be directly generated by a semiconductor laser, a wavelength conversion technology using a nonlinear crystal is applied to obtain those wavelengths. We have developed and produced patented 532, 561 and 594 nm compact visible lasers in which a semiconductor laser and nonlinear crystal are integrated in a compact package (Fig. 1). This article describes the features of these lasers.

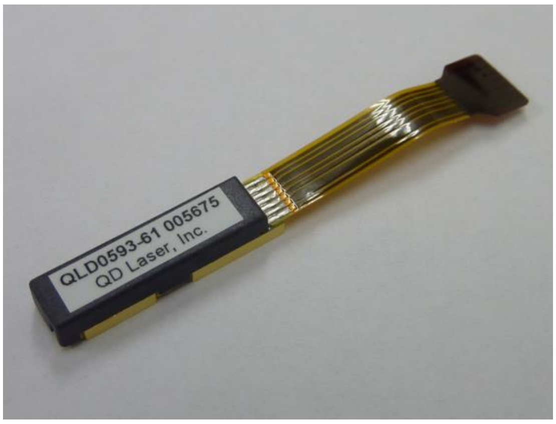


Fig. 1. Compact visible laser.

2. Feature of compact visible laser

The compact visible laser consists of two key components: a semiconductor optical amplifier integrated single frequency DFB laser (DFB: Distributed FeedBack), and a nonlinear crystal (Fig. 2).

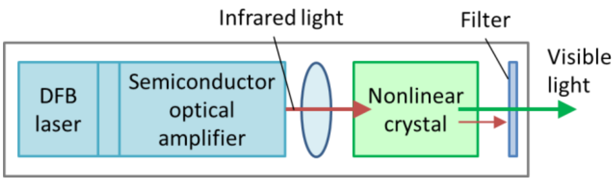


Fig. 2. Schematic structure of compact visible laser.

In case of the 561 nm laser, as an example, 1122 nm infrared light generated by the DFB laser is amplified by the semi-conductor optical amplifier. The 1122 nm light is converted to 561 nm by frequency doubling in the nonlinear crystal. Laser emissions at 532 nm (green), 561 nm (yellow-green) and 594 nm (orange) are obtained by a proper combination of lasing wavelength of the DFB laser and the phase matching wavelength of the nonlinear crystal (Fig. 3).

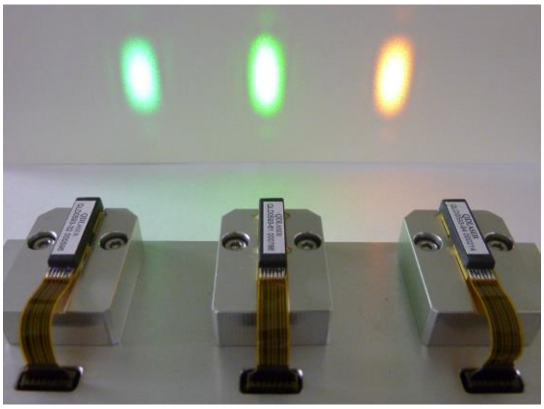


Fig.3. Green, Yellow-green, Orange laser.

The compact visible laser has following features:

[1] Single frequency and high stability (<2%)

[2] Compact package (<0.5 cc)

[3] Low power consumption (1.5 W, excluding power consumption of a laser driver)

[4] Direct modulation up to 100 MHz

[5] 50 picoseconds pulse generation.

Details in each feature are described below.

[1] Single frequency and high stability

Our DFB laser was realized by experts engaged in the development of lasers for optical communications of which requirement for the quality and reliability is very high. The two key technologies used for the laser are a grating formation technology in the semiconductor, and a regrowth technology to bury the grating and obtain a flat surface. Since the linewidth of the DFB laser is several MHz due to high selectivity of gratings for lasing wavelength, the visible light converted by the nonlinear crystal is also single frequency with narrow linewidth (Fig. 4).

In addition to that, the optical power stability is high because high stability of optical power generated by the DFB laser is directly transferred to the visible light. The feature of the product enables improvement of detection accuracy and resolution of an object.

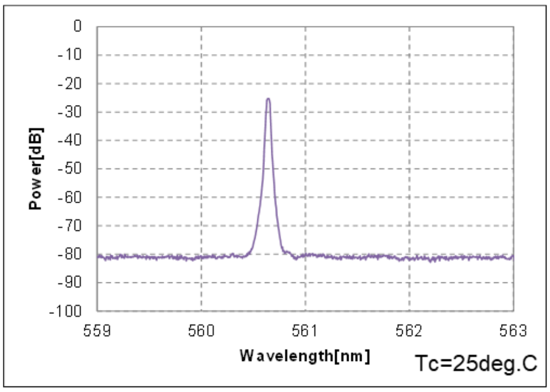


Fig. 4. Optical spectrum of 561 nm laser.

In case of a DPSS laser, a pump laser with multi-longitudinal modes excites a laser crystal to generate the infrared light. It is converted to the visible light through the nonlinear crystal. The stability of the DPSS laser is not as good as our laser because the stability of the infrared light generated by the multi-longitudinal mode laser is not high compared to the DFB laser.

[2] Compact package

Main components of DPSS lasers and OPSLs are the pump laser, laser crystal and nonlinear crystal. There are lens and mirrors in between for coupling, reshaping, and oscillation of the laser beam that makes it difficult to reduce the size of the package.

The compact visible laser with less than 0.5 cc (22 x 5.6 x t3.8 mm) in volume is realized by integrating the DFB laser and the semiconductor optical amplifier in single die, that enables us to reduce the number of main components to two, i.e., the DFB laser and nonlinear crystal. The compactness saves the space and increases the degree of freedom in layout inside the instruments.

[3] Low power consumption

In case of DPSS lasers and OPSLs, the laser crystal is excited by the pump light from the pump laser to obtain the infrared light, however 100% excitation efficiency is not achievable. In addition, since a shorter wavelength (higher energy) than the infrared light is required to excite the laser crystal, the energy corresponding to the difference between the pump light and the infrared light is lost. For example, if an 808 nm pump laser is used to obtain a 1064 nm infrared light which is the seed light for a 532 nm laser, the energy difference between 808 nm and 1064 nm becomes loss.

Since the compact visible laser emits infrared light directly by current injection, energy loss can be suppressed, and low power consumption of 1.5 W is achieved (excluding power consumption of a laser driver).

[4] Direct modulation up to 100 MHz

When the semiconductor optical amplifier is modulated by current while the output power of the DFB laser is kept constant, the output power changes with the change in the modulation current. Since the modulation band of the semiconductor optical amplifier is determined by the RC time constant as it is for the semiconductor laser, it is possible to modulate up to 100 MHz without using an external modulator.

The light can be absorbed by applying a reverse bias to the semiconductor optical amplifier. A high extinction ratio of 30 dB or more can be obtained by using a modulated signal with a combination of the forward and reverse bias.

[5] 50 picoseconds pulse

The DFB laser operates in the gain switching mode by injecting a short electrical pulse and generates a short optical pulse of around 50 picoseconds (Fig. 5). The gain switching mode is an operation mode that utilizes a phenomenon of a strong short pulse generation that occurs just after the laser reaches the lasing threshold. The ability to generate picosecond short pulses in the compact package is a unique feature of this product, and it is suitable for short pulse laser light sources for STED microscopes.

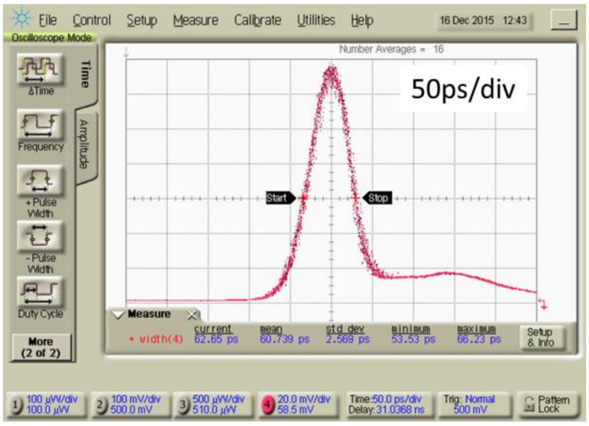


Fig. 5. Short pulsed operation.

Table 1 shows the features of [1]-[5] of the compact visible laser with a comparison to other companies' products.

Table 1. Comparison to other companies' products

		QD Laser, Inc.			Company A (OPSL)			Company B (DPSS laser)		
Wavelength (nm)		532	561	594	532	561	594	532	561	594
Output power (mW)		30, 50	5, 20, 30, 50	5, 20	20, 50, 80, 100, 150	20, 50, 80, 100, 150	20, 60, 100	300	100, 150	30, 50
Beam quality	Longitudinal mode	Singlemode			Singlemode			Singlemode		Multi-mode
	Ellipticity	≈ 1 : 2 (divergent light)			≤ 1 : 1.1 (collimated light)			≤ 1 : 1.1 (collimated light)		
	M2	≤ 1.2			≤ 1.1			< 1.1		< 1.2
CW characteristics	Stability	< 2%			< 2%			< ±2%		
	RMS noise	< 0.2%			< 0.25%			< 0.5%	< 0.2%	< 1%
Modulation characteristics	Frequency	< 100 MHz			< 1 kHz			N/A		
	Minimum pulse width	50 ps (gain switching mode)			≈ 1 ms			N/A		
Operation temperature		20 - 30°C			10 - 45°C			10 - 40°C		
Storage temperature		-10 - 50°C			-20 - 60°C			-20 - 60°C		
Power consumption		1.5 W Max (LD)			Typical 5 to 8 W, Max. 12 W (including driver)			< 60 W (including driver)		
Dimension / volume		22 x 5.6 x 3.8 mm / 0.5 cc (no TEC)			27 x 52 x 13.1 mm / 19 cc (optical head)			115 × 50 × 43.5 mm / 250 cc (optical head)		

3. Product lineup

3-1. Compact visible laser

Three types of compact visible lasers are currently available (Table 2). A standard type, which emits light into free space, offers an advantage of the compact package to increase the degree of freedom in the layout of optical systems and instruments.

A fiber-pigtailed type, of which output is from a single-mode fiber, emits a circular beam due to the nature of the optical fiber and the optical path can be easily changed, which helps simplify optics in the instrument. The standard type and fiber-pigtailed type require current sources and a temperature controller.

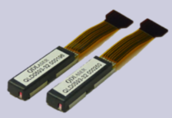
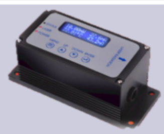
A CW driver integrated BOX has the driver and temperature control function housed in a box. Customers can use it immediately after purchasing.

3-2. Laser driver

A laser driver generates a 50 picoseconds optical pulse by operating a gain switching mode and is compatible with the standard type and fiber-pigtailed type. A laser driver that operates in CW mode and pulse mode at 100 kHz is under development.

Fig. 6. QBB0502 picosecond driver.

Table 2. Product lineup of compact visible lasers

		Standard type	Fiber-pigtailed type	CW driver integrated BOX
Appearance				
Part number		QLD0593-xxyy-11	QLD0561-xxyy	QC4D0593-xxyy
Wavelength		532, 561, 594 nm	532, 561 nm	532, 561, 594 nm
Light output		Free space	Optical fiber	Free space
Output power	CW to 100 MHz	532 nm : 20,30 mW 561 nm : 5, 20, 30, 50 mW 594 nm : 5, 20 mW	SMF/PMF: 15 mW MMF: 25 mW	20 mW CW only
	50 ps Gain switching mode	532 nm: 20 mW 561 nm: 50 mW 594 nm: 20 mW	15 mW	N/A
Required instruments		・Current sources: 2 units ・Temperature controller: 1 unit		PC

3-3. Multi-color compact laser light source

The multi-color compact laser light source includes one of our compact visible lasers and three TO-CANs of other wavelengths in a small package. One wavelength can be selected from 532, 561, and 594 nm for compact visible lasers, and up to 3 wavelengths can be selected from 405, 488, 520, 640, 660, and 785 nm for TO-CAN. For example, 405, 488, 561, and 640 nm are suitable for flow cytometers. By installing the compact visible laser, we have achieved high stability (<2%) and palm-sized housing even at 4 wavelengths. A laser driver for CW and pulse operation is also available as an option.

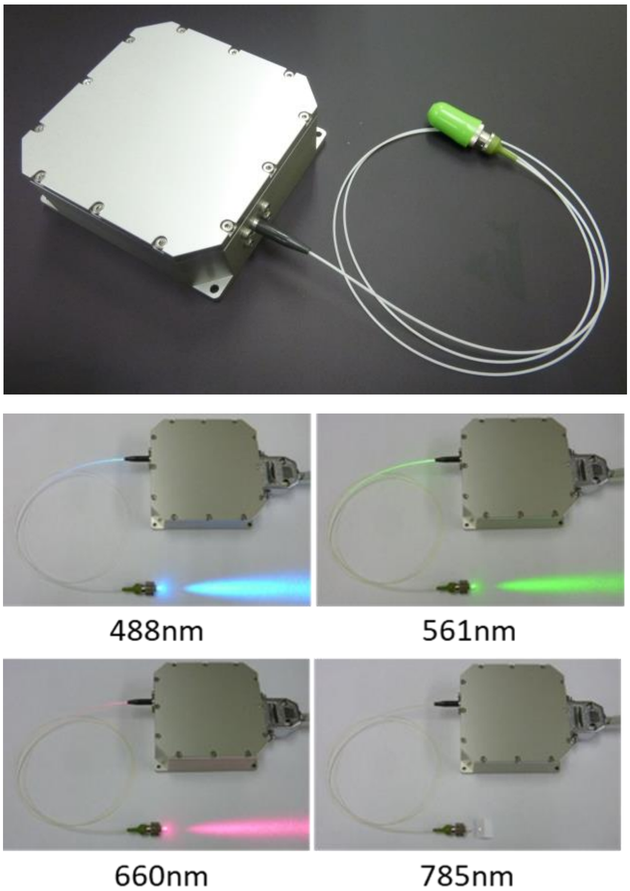


Fig. 7. Multi-color compact laser light source.

・Size: 80 x 80 x t30 mm

・Fiber output: SMF/PMF, 20 to 40 mW

4. Summary

We introduced 532, 561, and 594 nm compact visible lasers. Its compactness, low power consumption, and high stability are suitable for biomedical applications such as flow cytometers and fluorescence microscopes and contribute to improving the design freedom and functionality of customers' products.