Types of Blue Lasers

- Blue laser diodes, typically based on gallium nitride (GaN) or related materials, e.g. (In,Ga)N, and emitting around 400–480 nm, are relatively difficult to produce for high output power and long lifetime. Output powers of watts are possible. The pioneering company is Nichia, followed by Sony, Sharp, and SoraaLaser. The progress in this area is rapid, and it is to be expected that blue laser diodes will continue to exhibit improving performance and lifetime figures and will be widely used. A new development is that of blue-emitting VCSELs.
- Thulium-doped or praseodymium-doped up-conversion lasers based on fibers or bulk crystals can emit around 480 nm, typically with some tens of milliwatts of output power and with good beam quality. Further development for powers of hundreds of milliwatts or even multiple watts appears to be feasible.
- Helium–cadmium lasers (which are gas lasers) can emit hundreds of milliwatts in the blue region at 441.6 nm, with high beam quality.
- Blue or violet light can also be generated by frequency doubling (external to the laser resonator or intracavity) the output of lasers emitting around 800–1000 nm. Most frequently used are neodymium-doped lasers, e.g. Nd:YAG emitting at 946 nm (for 473 nm), Nd:YVO_4 at 914 nm (for 457 nm), and Nd:$YAlO_3$ at 930 nm (for 465 nm). Common nonlinear crystal materials for frequency doubling with such lasers are LBO, BiB_3O_6 (BIBO), $KNbO_3$, as well as periodically poled KTP and $LiTaO_3$. Output powers of multiple watts can be obtained, even with single-frequency operation and high beam quality, although less easily than with 1-µm lasers. Instead of a laser, an optical parametric oscillator may be used.
- High-power optically pumped VECSELs are also very attractive laser sources for frequency doubling with several watts or even tens of watts of output power. Note that other kinds of semiconductor lasers, such as broad area laser diodes, are available with suitable wavelengths, but are less suitable for frequency doubling due to a typically broader linewidth and poor beam quality. There are some diode lasers, however, which deliver some tens of milliwatts of frequency-doubled light.
- Argon ion lasers, based on laser amplification in an argon plasma (made with an electrical discharge), are fairly powerful light sources for various wavelengths. While the highest power can be achieved in green light at 514 nm, significant power levels of several watts are also available at 488 nm, apart from some weaker lines e.g. at 458, 477 and 497 nm. In any case, the power efficiency of such lasers is very poor, so that tens of kilowatts of electric power are required for multi-watt blue output, and the cooling system has corresponding dimensions. There are smaller tubes for air-cooled argon lasers, requiring hundreds of watts for generating some tens of milliwatts.

For wavelengths below $\approx$400 nm, the eye's sensitivity, i.e. its ability to detect small light levels, sharply declines, and one enters the region of ultraviolet radiation. Note that even for wavelengths around or slightly above 400 nm, the retina can be damaged via photochemical effects even for intensity levels which are not perceived as very bright.

Applications of Blue and Violet Lasers

Blue and violet lasers are used e.g. in interferometers, for laser printing (e.g. exposure of printing plates) and digital photofinishing, data recording (*Blue-ray Disc player*, *holographic memory*), in laser microscopy, in laser projection displays (as part of RGB sources), in flow cytometry, and for spectroscopic measurements. Data recording is one of the major drivers for the development of blue laser diodes. In most cases, the use of blue and violet lasers is motivated by the relatively short wavelengths, which allows for strong focusing or resolving very fine structures in imaging applications.