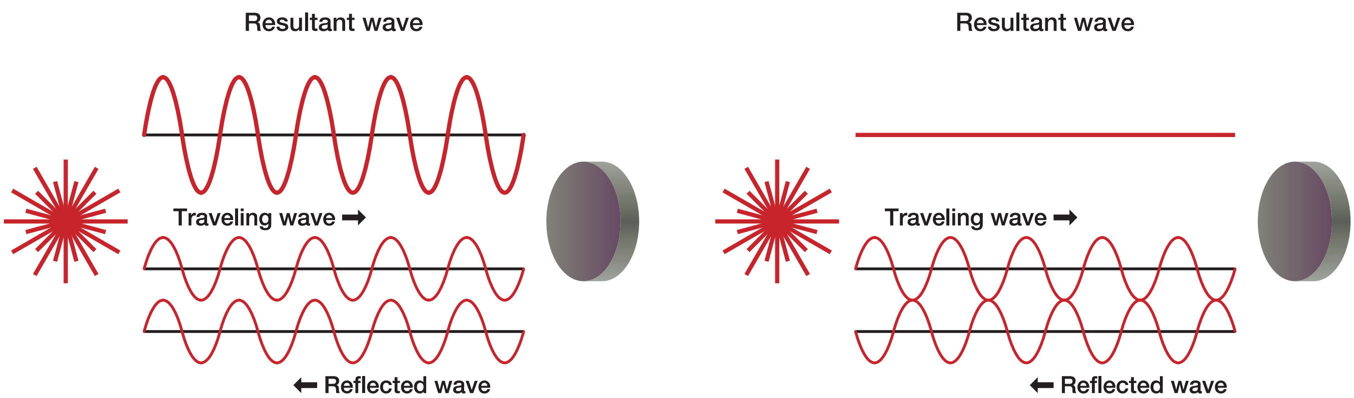
Quantum Cascade Laser (QCL)

Optical noise characteristics of CW Quantum Cascade Laser with built-in lens

Measurement example of fringe noise (interference noise)

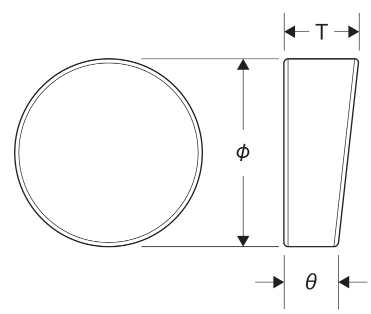
In spectral single-mode laser applications, suppressing optical interference will greatly contribute to improving the S/N of the system. The emitted laser light is reflected a little by the optical elements of the system such as lenses and detectors. Interference occurs because the light becomes strong (constructive interference) at the point where the traveling wave and the reflected wave are in phase, and the light becomes weak (destructive interference) at the part where the two waves have opposite phases. Especially in single-mode lasers with higher spectral coherence, the interference is especially noticeable in single-mode lasers with higher spectral coherence, which greatly affects the S/N of the system.



If the interference condition is fixed, it is easy to improve S/N. However, for example, due to changes in the emission wavelength of the laser or slight changes in the optical path length due to vibration or temperature change of the system, the interference conditions change over time and the improvement of S/N is not easy.

Especially in applications with intentional scanning of the wavelength of the laser, it is very difficult to eliminate interference. In order to eliminate interference, it is a common measure to insert an optical isolator into the optical path where interference occurs, but there is an issue with availability and cost of the mid-infrared isolator [1].

The interference pattern caused by interference is called fringe. In order to suppress the fringe, adding a non-reflective coating to optical elements such as lenses and windows is effective, and it is also effective to tilt the laser, the detector and the optical elements, etc. so as not to cause specular reflection. And also, the front and rear surfaces of a parallel plate such as windows may cause interference. Interference between the front and back surfaces of a



parallel window can be suppresed by using a wedged window instead. The wedged angle varies depending on the situation in which interference occurs, but it seems that in many cases, the effect is generally obtained at about 3 to 10 degrees.

The ease at which fringe occurs depends on the coherency of the laser. Fringing occurs easily with CW single-mode lasers with excellent coherency, whereas pulsed single-mode lasers, which are inferior in coherency, generate relatively less fringing.

In HAMAMATSU quantum cascade lasers, fringe suppression has been realized through careful design of the package and the optical components. Below is an experimental result [2] of fringe evaluation of the CW quantum cascade laser with built-in lens. Fringe was evaluated in a typical gas measurement configuration using a CW quantum cascade laser with built-in lens (Fig. 1).

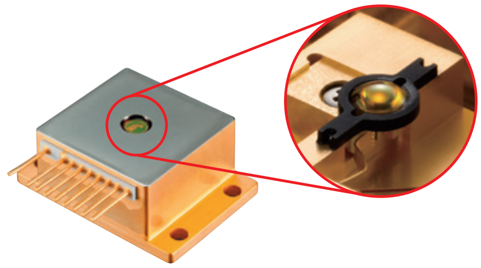
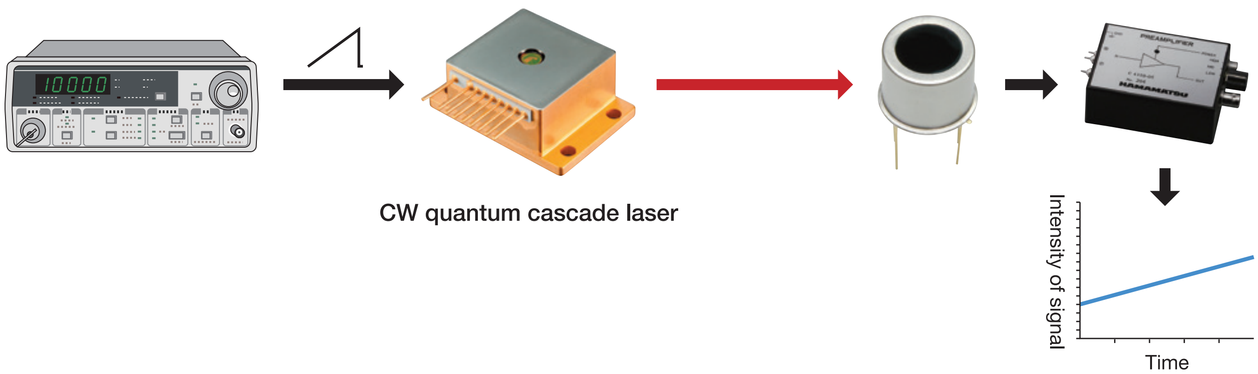


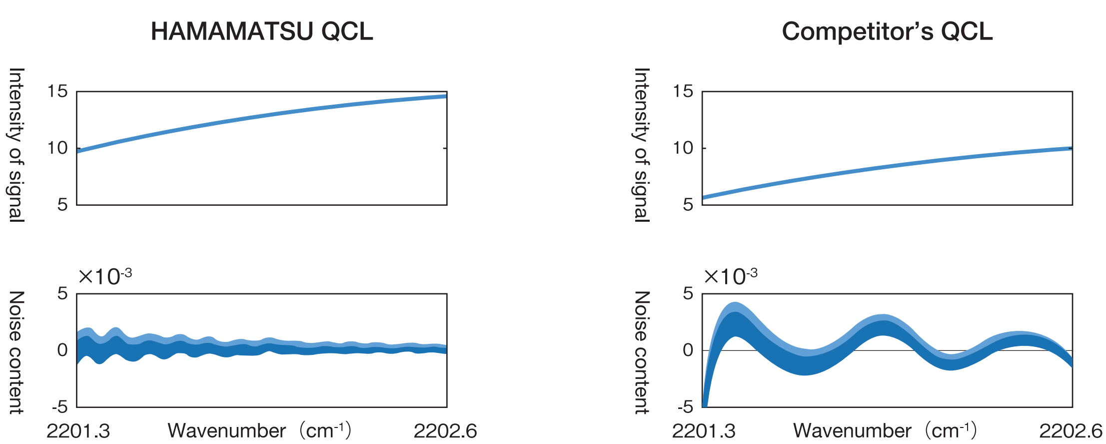
Figure 1



The forward current to the CW quantum cascade laser was increased at a constant rate and simultaneously emission wavenumber, i.e., wavelength was continuously scanned about 1 cm^{-1} by means of current modulation. According to the current modulation, the signal intensity from the detector increased as the forward current of the CW quantum cascade laser increased.

Figure 2 shows a graph obtained by converting the horizontal axis to the emission wavenumber. In addition, the lower graph of Fig. 2 shows a graph in which the linear increment of the detector signal due to the increase in the forward current of the CW quantum cascade laser is removed and the vertical axis is enlarged.

Figure 2



It can be seen that periodic fringe is observed as the emission wavenumber is scanned. The larger the amplitude of the fringe, the more the system S/N will be compromised. For comparison, the experimental results using another company's CW quantum cascade laser with built-in lens under the same experimental conditions are also shown. It is found that our lens built-in CW quantum cascade laser has lower fringe amplitude, resulting in lower optical noise.

In order to suppress the fringe, adding a non-reflective coating to elements such as lenses and windows is effective, and it is also effective to tilt the laser, the detector and the optical elements, etc. so as not to cause specular reflection. However, specific measures depend on the system and optical system. Also, since there are many reflection interfaces in the system, it is finally observed as a complex fringe with different period and amplitude. It is important to carefully identify the cause of fringe and consider countermeasures.

References

[1] Electro-Optics Technology, Inc.

[2] Xuehui Guo, et al., Development and evaluation of a QCL-based Open-path N2O sensor, MIRTHE+ Symposium, 10/3-4/2016, City College of New York (not published).

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