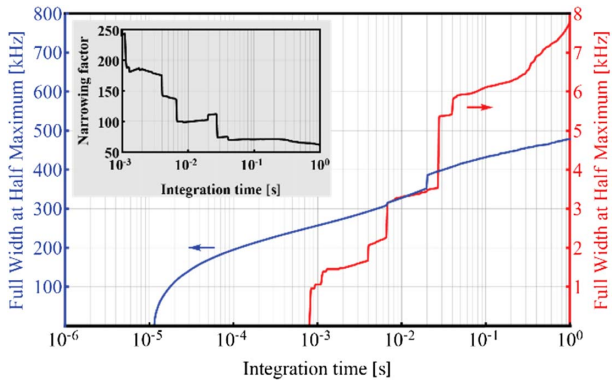

Fig. 5. FWHM linewidth of the QCL calculated from the frequency noise spectrum based on the β-separation line approximation [23] as a function of the integration time (inverse of the lower cutoff frequency for the FN-PSD integration) in a free-running regime (blue) and for the QCL stabilized to the delay line (red). Inset: linewidth narrowing factor as a function of the integration time.

responsible for the observed laser frequency noise that is no longer limited by the detector or intensity noise.

The laser linewidth estimated from the measured FN-PSD using the β-separation line approximation [23] is 7.8 kHz at 1 s integration time, which is 60 times narrower than the linewidth of the free-running laser (Fig. 5). This reduction factor is even larger than 100 at shorter integration times of 10 ms and below. The achieved linewidth narrowing is much higher than with other simple approaches previously reported for frequency noise reduction in QCLs [10,11], while being obtained with a fairly simple setup consisting of only of a few standard optical components (two gold-coated mirrors and two polarization-independent beam splitters in the interferometer). This simple arrangement does not involve any vacuum chamber, temperature stabilization of the setup, or active anti-vibration platform.

In conclusion, we have reported, to the best of our knowledge, the first proof-of-principle demonstration of QCL frequency noise reduction using a free-space delay line. The achieved results are presently limited by the implemented self-homodyne scheme and by the fact that a fairly short imbalance pathlength (less than 1 m) is used in this experiment. The next steps to improve the stabilization will consist on one hand of increasing the pathlength difference to enhance the sensitivity to the laser frequency noise and decrease the stabilization noise floor, which can be achieved for instance with the use of a multipass cell to keep the setup compact. On the other hand, we will implement an absolute lock of the delay line to a molecular transition to combine the linewidth reduction brought by the stabilization to the delay line with the absolute frequency stability of the molecular reference.

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