Broadband loss measurements in passive and active mid-infrared waveguides using Fabry-Pérot resonances

M. Carras, E. Peter, C. Sirtori, M. Garcia and X. Marcadet

***Abstract*— We demonstrate a new technique to measure optical gain/loss of quantum cascade laser ridges, based on a broadband Fabry-Pérot resonance technique. This as well as the refractive index is determined between 2.5 and 8 microns. The technique is suitable for both active and passive waveguides.**

***Index Terms*— Quantum cascade lasers, mid-infrared, gain and losses.**

Measurement of waveguide propagation losses is a key point for the enhancement of laser performances and in particular the reduction of the threshold and the optimization of the wall plug efficiency. To this end, many different methods have been developed. Among those, the Fabry-Pérot technique has been demonstrated for low-loss measurements, in the near-infrared [1-3] and since recently in the mid-infrared [4]. The latter is based on the measurement of fringes arising from the interferences in the cavity.

We propose in this paper to use the Fabry-Pérot cavity technique with a thermal source. This source is broad and thus we obtain a simultaneous determination of the optical waveguide properties , loss and index, on a large wavelength range, that is 2,5µm to 8µm. Moreover, this technique can be applied to a wide variety of waveguides since it is suitable for active as well as passive devices. Figure 1 shows the Experimental set-up of gain/loss measurements with a thermal source The latter is the glow bar of a Fourier Transform Infrared spectrometer (FTIR), emitting in the 2-25 µm range. The collimated beam of the glow bar is focused onto the cleaved front facet of a waveguide ridge using a high numerical aperture microscope objective (M1). The diameter of the focused spot is estimated to be about 15 microns. The light transmitted by the waveguide, emerging from the rear facet, is collected by a second identical microscope objective (M2), which insures a spatial selection and avoid collecting both the substrate radiation mode and the stray light.

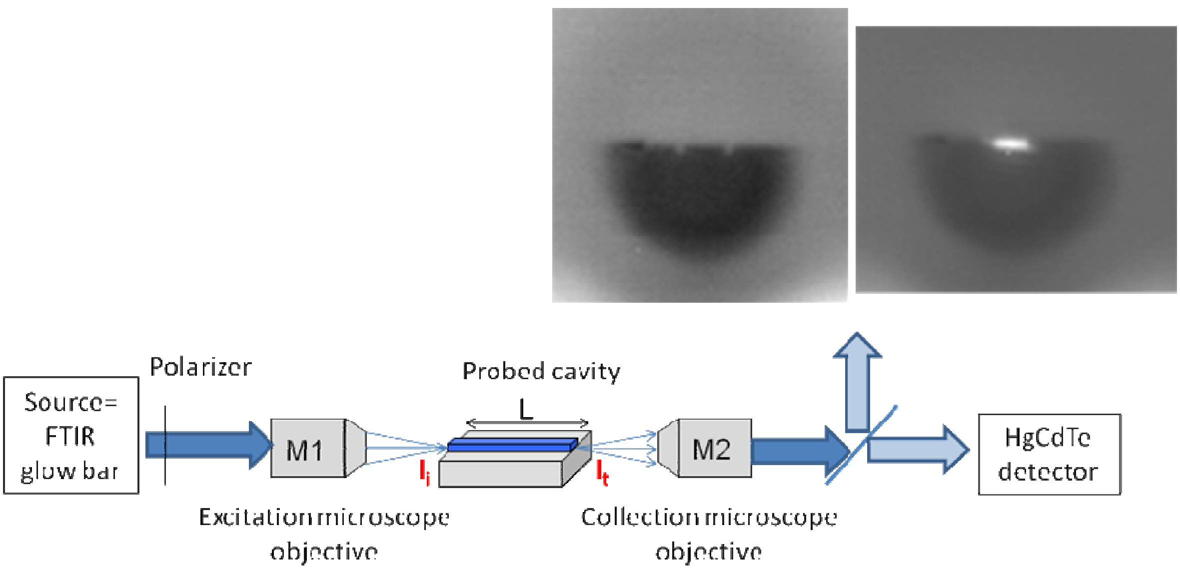

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Fig.1 : Setup of the transmission measurements using a broadband glow bar source and a QWIP camera for imaging.

The key point is the imaging the rear facet without illumination by the glow bar with the QWIP camera. After that the source is injected in the waveguide. Then we image simultaneously the rear facet and the transmitted beam, as shown in figure 1. Imaging is also crucial to check that we do select the light transmitted by the waveguide. However, the camera cannot be used as a detector coupled with the FTIR since its frequency acquisition is not fast enough (166Hz). The transmitted beam is then focused onto a liquid nitrogen cooled HgCdTe detector, sensitive in the 2-15 µm range and spectrally analyzed by the FTIR. The polarizer allows making measurements for TE (electric field perpendicular to the growth direction) and TM polarizations (electric field parallel to the growth direction).

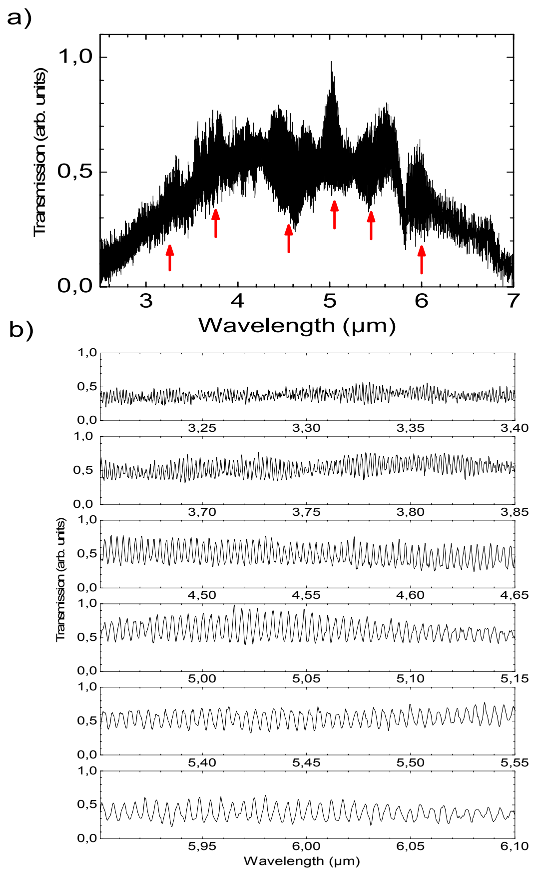

Fig. 2: a) Transmission spectrum. The 6 red arrows correspond to the 6 regions where a zoom is performed in figure 2b. b) Zoom on the 6 regions on a 0.2 nm range.

We illustrate this method by studying the waveguide of a InGaAs/AlInAs quantum cascade laser designed to emit at 4.8µm. depending on the wavelength we can see various behavior from single-mode transmission to multimode transmission. This allows both the determination of the losses in the single-mode case as well as the evaluation of losses of higher order modes.

REFERENCES

[1] M. Seto, A. Shahar, R.J. Deri, W.J. Tominson and A. Yi-Yan, Applied Physics Letters 56, 990 (1990)

[2] R. G. Walker, Electronics Letters, 21, 581 (1985)

[3] L. Lanco, S. Ducci, J-P. Lifkorman, P. Filloux, X. Marcadet, M. Calligaro, G. Leo and V. Berger, Applied Physics Letters, 90, 021105 (2007)

[4] D.G. Revin, L.R. Wilson, D. A. Carder, M. J. Steer, M. Hopkinson, R. Airey, M. Garcia, C. Sirtori, Y. Rouillard, D. Barate, and A. Vicet, Journal of Applied Physics, 95, 7584 (2004)