Mid-Infrared Imaging Spectroscopy with Broadband Quantum Cascade Lasers

– SUPPLEMENTARY INFORMATION –

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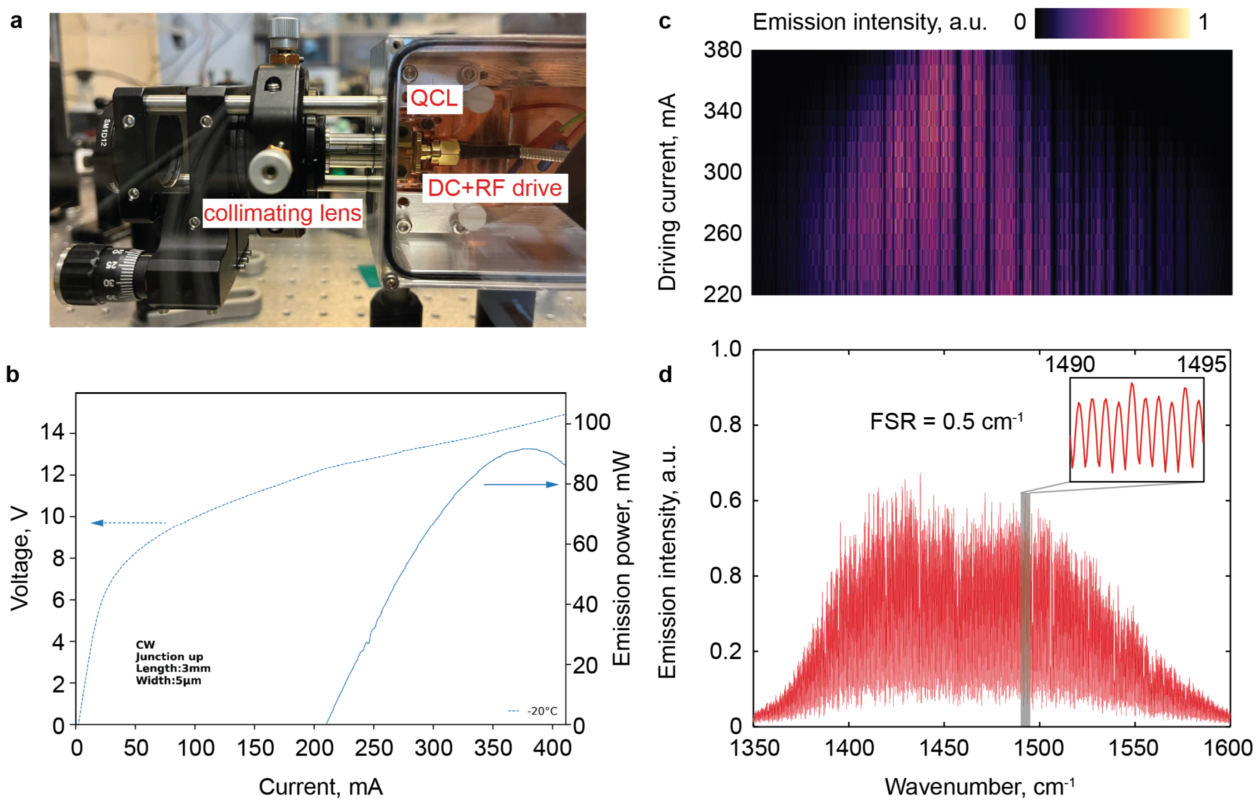

Figure S1: **a**, Photo of the quantum cascade laser assembly. **b** I-V and emission intensity curves of the QCL chip used in the experiments. **c** Dependence of QCL emission spectra on the bias current for 29 dBm, 500 MHz RF drive. Dark lines correspond to water vapour absorption present in the setup during the measurements. **d** Measured QCL emission spectra for 220 mA bias current and 29 dBm, 500 MHz RF drive with setup purged with dry air. The inset shows the FSR of the laser emission lines.

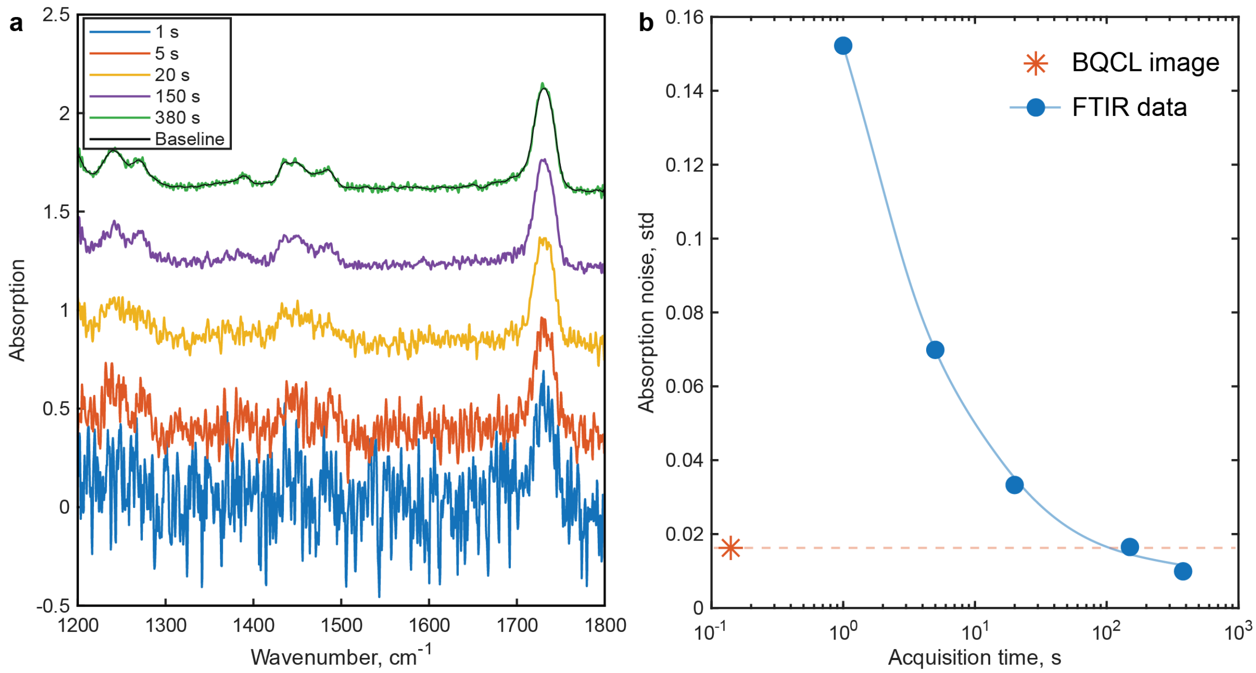

Figure S2: **a**, Absorption spectra of 800 nm PMMA layer on CaF_2 chip measured for different acquisition time (number of averages), illustrating the reduction of noise level with longer measurement. Each consecutive spectrum is shifted vertically by 0.4 to facilitate the comparison. **b,** Dependence of the noise level calculated as the standard deviation from the absorption baseline (shown with black curve on top of 380 s spectrum in panel a). The BQCL noise was estimated as standard deviation from the absorption baseline, smoothed from the original data from Fig. 2e of the main manuscript using a 40-point moving average.

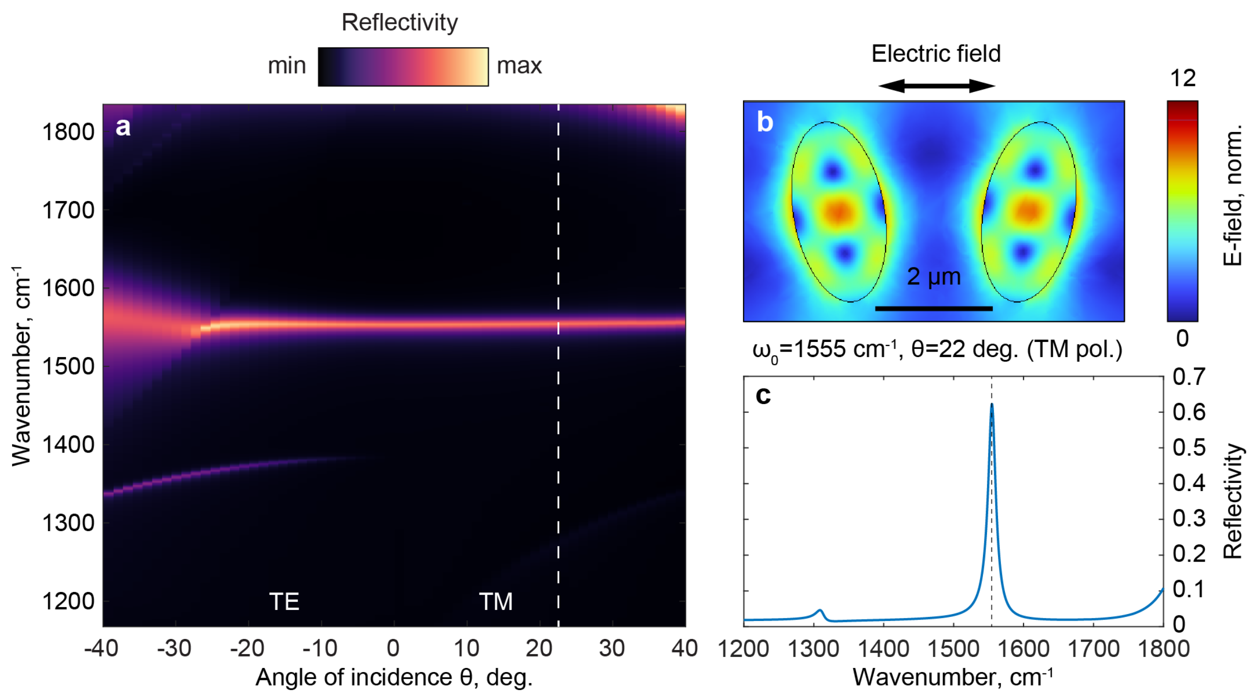

Figure S3: **a**, Simulation of the local reflectivity of the gradient metasurface depending on the angle of incidence. The unit cell scaling is chosen to match the metasurface resonance frequency with the higher frequency limit of the broadband quantum cascade laser. The corresponding parameters of the unit cell are: period 6.48×3.744 µm^2, ellipse long axis 3.096 µm, ellipse short axis 1.548 µm, ellipse height 0.7 µm, ellipse tilt angle 10° (see also panel b). The electric field aligned along the long axis of the unit cell. Left half of the map corresponds to TE polarization (plane of incidence orthogonal to the long axis of the unit cell), right half - to TM polarization (plane of incidence parallel to the long axis of the unit cell). The metasurface is assumed to be infinitely periodic in both directions. Dashed line indicates the excitation geometry used in the experiment (TM polarization, angle of incidence 22 degrees). **b**, Map of the electric field in a horizontal cut plane at half the height of Ge resonator (0.35 µm) at the resonance frequency of 1555 cm^{-1}. The structure is excited with a TM-polarized plane wave at 22 degrees angle of incidence to emulate the geometry of the imaging SEIRA experiment. **c**, reflectivity spectrum of the metasurface with the same parameters as in panel b. Dashed line shows the metasurface resonant frequency.

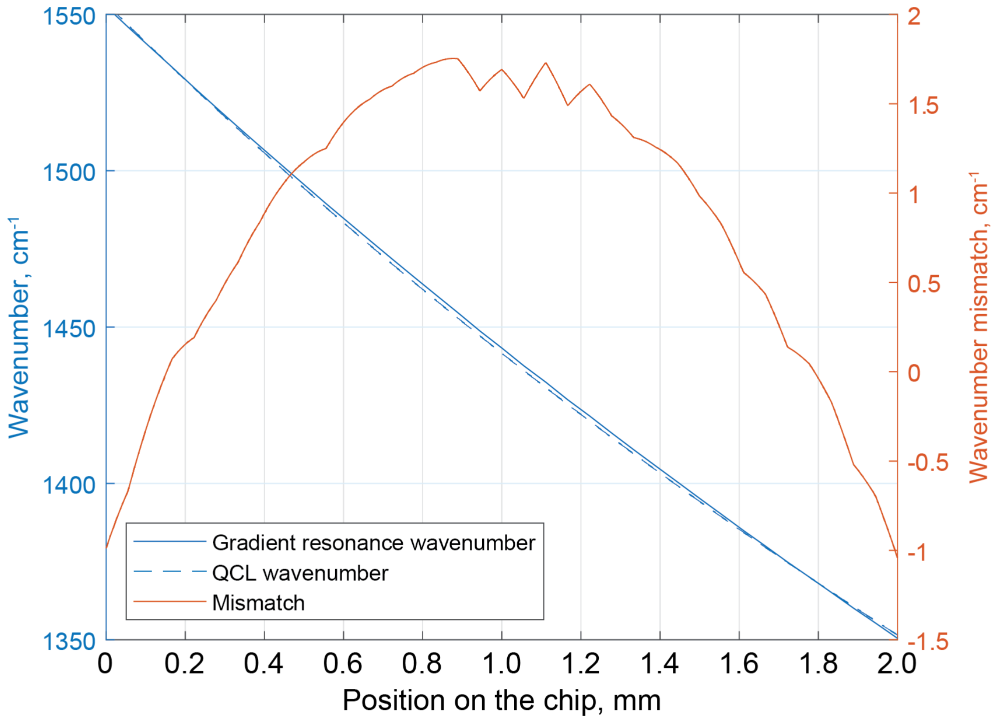

Figure S4: Matching of the metasurface resonance gradient with the dispersion of the QCL spot. Blue solid curve: designed spatial dependence of the resonant wavenumber on the gradient chip. Blue dashed curve: calculated spatial distribution of the wavenumber in the QCL diffraction spot. Red curve: mismatch between these two values. For the proposed design, the absolute value of mismatch does not exceed 2 cm^{-1}, which is considerably smaller than the characteristic resonance linewidth ($\sim$ 25 cm^{-1}).