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Supplementary Materials for

Giant optical nonlinearity interferences in quantum structures

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Supplementary Materials

THz confinement in the etched QCL

Figure S1 presents simulations of the THz electric field confined in a metal-metal waveguide, viewed from the side of the laser ridge, with one slit etched in the top metal layer (left simualtion) and two slits etched in the top layer (right simulation). For the 150-μm-wide ridge, the slits are 3-μm-wide, and are seperated by 45 μm in the two-slit configuration. The total THz field resulting from both the first and second confined modes in the modified waveguide is measured at vertically under the slit. It is stronger for the two-slits configuration (474 V/cm) compared with the one-slit configuration (337 V/cm), and as such the former configuration was chosen to maximize the overlap between the THz electric field and the resonant NIR excitation, under the slit.

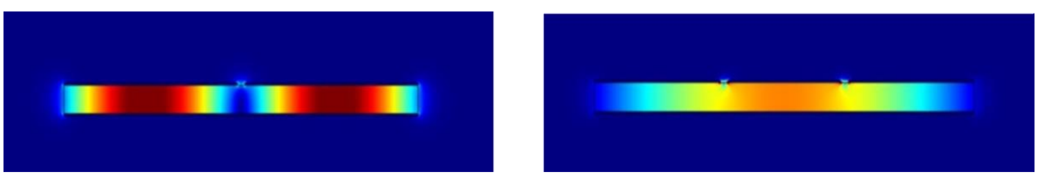

Fig. S1. Simuations of THz mode confinement in a double-metal QCL with one (left) and two (right) apertures in the top metal layer.

Bandgap shift due to thermal dissipation

As reported in ref (*29*), when the QCL is biased over threshold, a bandgap shift is observed due to a local temperature increase from the electrical power dissipated in the QCL. We also observe a bandgap shift in our experiment, by measuring the photoluminescence from the biased QCL facet, plotted in fig. S2. By comparison with the expected first electron-hole overlaps at 10 K (black stars in fig. S2, for an expected bandgap at 1.519 eV), we require an energy shift of the calculated bandgap by 13 meV to account for the electrical power dissipation.

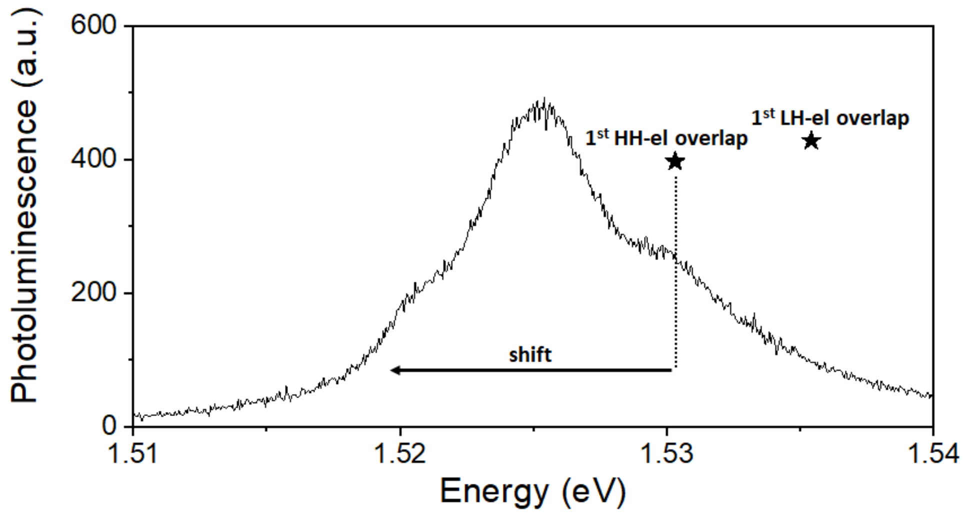

Fig. S2. Photoluminescence (PL) spectrum measured in reflection on a QCL facet when the QCL is biased at the threshold voltage. Since considerable electrical power is dissipated in the structure, the PL spectrum is red shifted compared with the expected spectrum at 10 K. The first HH-el and LH-el transitions, indicated by the black stars, need to be shifted by 13 meV to account for the PL shift due to the large dissipated electrical power.

$|\chi^{(2)}|^2$ for different applied electric fields

We calculate $|\chi^{(2)}|^2$ for different applied electric fields, from 7 kV/cm to 12 kV/cm, presented in fig. S3 with different colour lines representing different electric fields. We observe that the depths and positions of the energy minima are tuned with the electric field. We demonstrate with these simulations that the positions in energy of these minima are very sensitive to the bandstructure profile. The nonlinear susceptibility could then be engineered by controlling the wavefunctions and applied electric field.

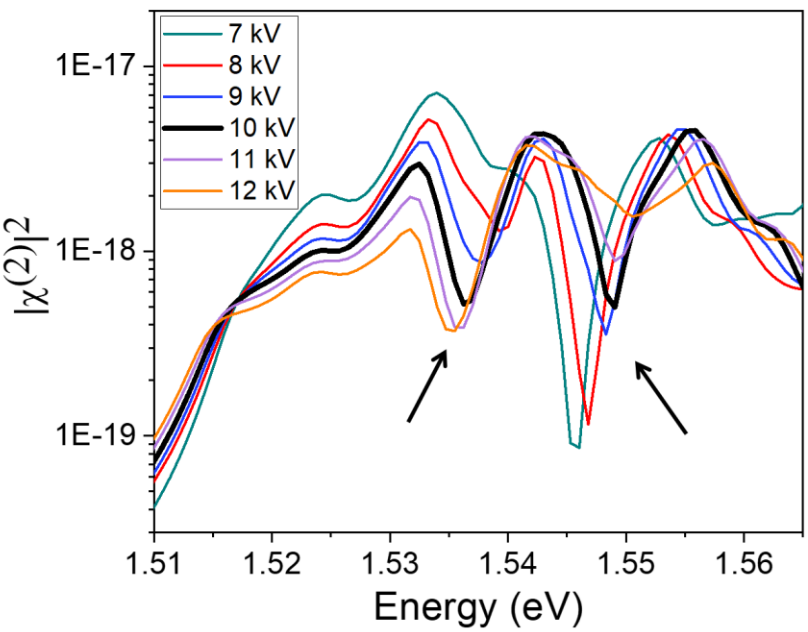

Fig. S3. Modulus squared $|\chi^{(2)}|^2$ calculated in reflection geometry for different electric fields applied to the structure, from 7 to 12 kV/cm, as a function of energy.