Poster Session

1. Eleanor Nuttall, Yingjun Han, Nick Brower, Matthew Oldfield, Lianhe Li, Alexander Giles Davies, Edmund Linfield, Brian Ellison, Paul Dean, Daniel Stone, Julia Lehman and Alexander Valavanis
   Analysis of deuterium reactions using self-mixing in a terahertz quantum-cascade laser

2. Esam Zafar, Olivier Auriaчемbe, Thomas Rawlings, Nick Brower, Matthew Oldfield, Yingjun Han, Lianhe Li, Edmund Linfield, Alexander Giles Davies, Brian Ellison, Paul Dean and Alexander Valavanis
   Electromagnetic modelling of a terahertz-frequency quantum-cascade laser integrated with dual diagonal feedhorns

3. Yezhezi Zhang, Alex Song, Deborah Sivco and Claire Gmachl
   Loss Compensation Scheme Using Metamaterials with a Quantum Cascade Structure

4. Sara Kacmaz, Yezhezi Zhang, Mei Chai Zheng, Abhanti Basak, Deborah Sivco and Claire Gmachl
   Low Inversion Active Region Design for Quantum Cascade Superluminescent Emitters

5. Ming Lyr, Loren Pfeiffer, Ken West and Claire Gmachl
   Long-wave Infrared (6-14 μm) GaSb/Al0.33Ga0.67As Quantum Cascade Lasers

6. Paris Blaisdell-Pitun, Claire Gmachl, Sankaran Sundaresan, and Bruce Koel
   Broadband Mid-Infrared Scattering of Highly Porous Alumina Catalytic Support

7. Borislav Hinkov, Jakob Hayden, Rolf Szegediak, Pedro Martin-Mateos, Borja Jerez, Pablo Acedo, Bernhard Lendl and Gottfried Strasser
   High frequency modulation of mid-IR ring and ridge DFB Quantum Cascade Lasers

   Superradiant meta-atoms strongly coupled to intersubband transitions

9. Johannes Hilbrand, Dominik Auth, Marco Piccardo, Federico Capasso, Gottfried Strasser, Stefan Breuer and Benedikt Schwarz
   Frequency comb dynamics of ultrafast quantum dot lasers

10. Chao Xu, Siyi Wang, Hosung Kim, Zbigniew Wasielowski and Daway Ban
    A 3.3 THz patch antenna terahertz photodetector

11. Boyi Wei, Chao Xu, Siyi Wang, Sm Shazad Rassel, Manasa Kanishev, Chris Deimert, Zbigniew Wasielowski and Daway Ban
    Novel 3-well THz QCL with hybrid injection/extraction channels

12. Kai Xi Wang, Stephen Hughes and Daway Ban
    Influence of electron-phonon scattering in quantum dot cascade lasers

13. Martin Fränkler, Johannes Popp, Michael Faider, Christian Jiratsek and Jerome Faist
    Numerical Optimization of Mid-IR QCL Frequency Combs

14. Tudor Olariu, Mattias Beck, Jerome Faist and Giacomo Scalari
    Dispersion measurements of terahertz Quantum Cascade Fabry-Perot cavities and VECSELS

15. Reana-Cristina Benescu-Chelmon, Yannick Salamin, Francesca Fabiana Settembrini, Yuriy Fedoryshyn, Wolfgang Heni, Delwin L. Elder, Larry Dalton, Jerg Leuthold and Jerome Faist
    Integrated ultrastable broadband terahertz field detectors in silicon photonics

16. Bagolini, Montanari, Ciano, Persichetti, Di Gaspare, Capellini, Zozzoler, Skibitzki, Stark, Scalari, Faist, Paul Grange, Birner, Baldassarre, Ortolani, De Seta and Michele Virgilio
    Optically pumped n-type Ge:SiGe asymmetric coupled quantum wells for THz emission

17. Laurent Bouly, Adel Roussos, Thomas Maertian, Raffaele Colombelli, Andrey Babichev, Anton Egorov and Grigoris Sokolovskii
    Tunable Mid-Infrared Metasurfaces on III-V semiconductors

18. Claire Abadie, Stefano Pirotta, Lianhe Li, Xavier Lafosse, Bruno Paulillo, Edmund Linfield, Alexander Giles Davies and Raffaele Colombelli
    THz: sub-wavelength detectors and lasers based on LC resonators

    Highly sensitive and compact THz heterodyne receiver based on HEB and QCL at 2.7 THz
Superradiant meta-atoms strongly coupled to intersubband transitions

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Abstract In this contribution, we will investigate the effects arising when coupling a metamaterial surface supporting a superradiant energy loss to intersubband transitions in the terahertz regime.

1. Introduction

Starting with the early investigations of harmonically driven two level systems, the research field of light matter interaction has gained more and more attention in the last decades. Progress in time lead to increasing interaction strengths reaching first the strong- and nowadays even the ultrashort coupling regime in which it is possible to observe completely new quantum phenomena[1]. The enormous dipole moment of intersubband transitions yield the ideal framework for ultrashort coupling experiments in the terahertz regime with coupling strengths on the order of the bare transition energy[2]. Here, we want to focus on the cavities used in these types of experiments, which are mostly based on single- or double metal metamaterial structures. We investigate, if the general assumption of non-interacting elements is justified, especially under the condition of subwavelength arrangement, i.e. when the radiative metamaterial response can be substantially influenced by their arrangement[3].

2. Experiment

We present a comprehensive study based on time-domain-spectroscopy. The samples we investigate are based on planar metamaterial resonators interacting with intersubband transitions in quantum well semiconductor heterostructures[4]. This system has the advantage, that it is possible to use an increased number of interacting electrons, which then directly affects the measured vacuum Rabi frequency[5]. The general assumption in these kinds of experiments is that there is no cavity interaction, i.e. each cavity is independently coupling to $\mu$ electrons. As a consequence, the vacuum Rabi frequency will not be influenced by the number of resonators.

A metamaterial surface consists of many elements in order to increase the amplitude response of the measured (in our case) transmission signal. We have shown that the density of meta-atoms can have substantial influence on the radiative losses of these elements[3]. In that way, we are able to control their radiative response due to their subwavelength arrangement.

In this study we want to focus on the two abovementioned effects often neglected in ultrastrong coupling experiments. First, we investigate the general possibility to include cavity losses in the metamaterial – intersubband transition system, which manifest themselves as additional loss terms in the Hamiltonian describing the system. A lossy cavity is then expected to shift the system to the weakly coupled Purcell regime [6]. Second, we investigate the effects arising when using a metamaterial surface supporting a superradiant energy loss.

Measurements at room temperature enable us to characterize the cavity losses, as shown in Fig.1 (red points: measured data, lines: Lorentzian fits). By taking the transmission spectra at liquid Helium temperature (blue), we are then able to draw conclusions about the polarization properties of the ultrashort coupled system. In this way, it is possible to compare the system’s response for the usual, non-interacting cavity approach with the one featuring an increased radiative cavity loss due to their interaction.

Surprisingly, our results show, that it is still possible to observe the formation of polaritons without being able to reach the expected Purcell regime. With the derived modified Hamiltonian, we are then able to calculate the vacuum Rabi frequency for a superradiantly decaying metamaterial surface coupled to intersubband transitions in the THz regime.

Figure 1: The meta-atom transmission spectra measured at room temperature (RT) show an increasing linewidth for meta-atoms interacting in the lossy cell, whereas the polaritons measured at liquid Helium temperature (LHe) remain robust.

References