Tamm plasmons and exciton polaritons in hybride microcavities

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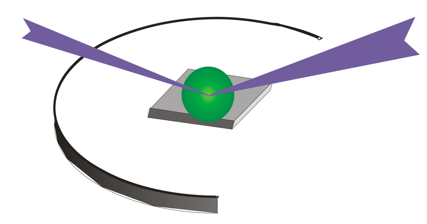


Motivation

Strong light-matter coupling in microcavities (MCs)

Utilization of generated polaritons for new class of optoelectronic devices

Tamm plasmons on MC structures

- Modulation of polariton energy
- Electrically tunable polariton devices

Bragg polariton samples

- Incorporation of many QWs for large coupling strength without increasing the mode volume

II-VI materials

Large exciton binding energies — Good structural quality [1, 2]

High oscillator strengths f — Promising for elevated-temperature applications

Strong coupling achieved in ZnSe-based microcavities

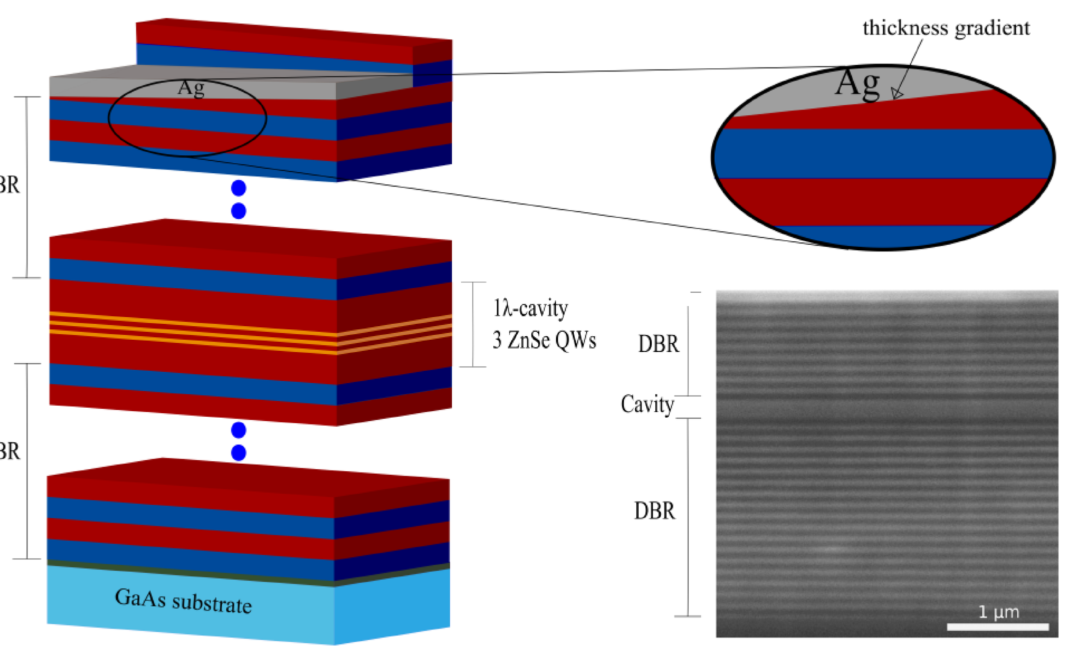
→ at 4 K with only three QWs – Rabi energy $\hbar\Omega_{3QWs}=19$ meV [1]

→ up to 220 K with 15 QWs [3]

→ polaritonic lasing in micropillars[4]

Tamm plasmons and exciton polaritons

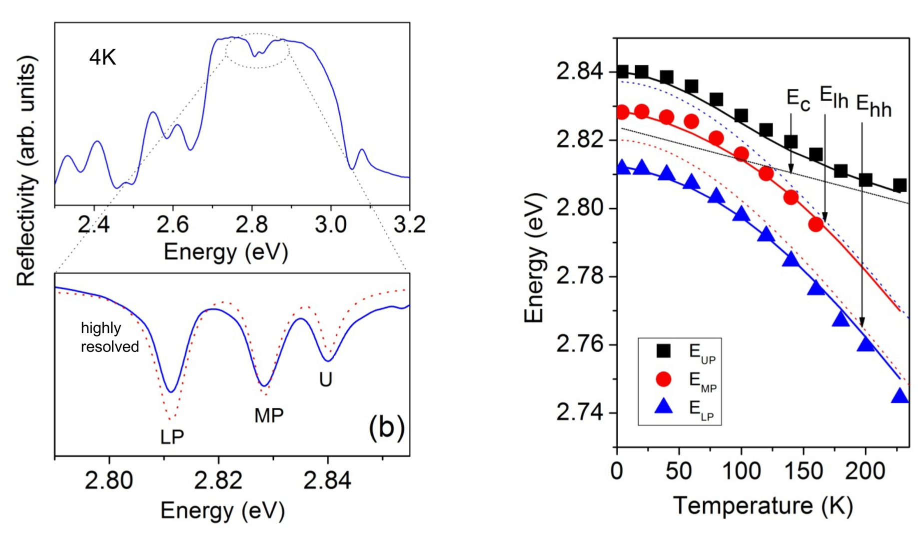
Sample setup



SEM image of the MBE gown sample

Thickness gradient of top DBR layer etched by CAIBE

Strong coupling between QW excitons and cavity mode



1 λ – 3 QWs

At 20K

$\Omega_{c\text{-}hh} \approx 17.5$ meV

$\Omega_{c\text{-}lh} \approx 12$ meV

Two anticrossings of the cavity mode with X_{hh} and X_{lh}

Clear signature of strong coupling regime

Total splitting LP – UP: 29.5 meV

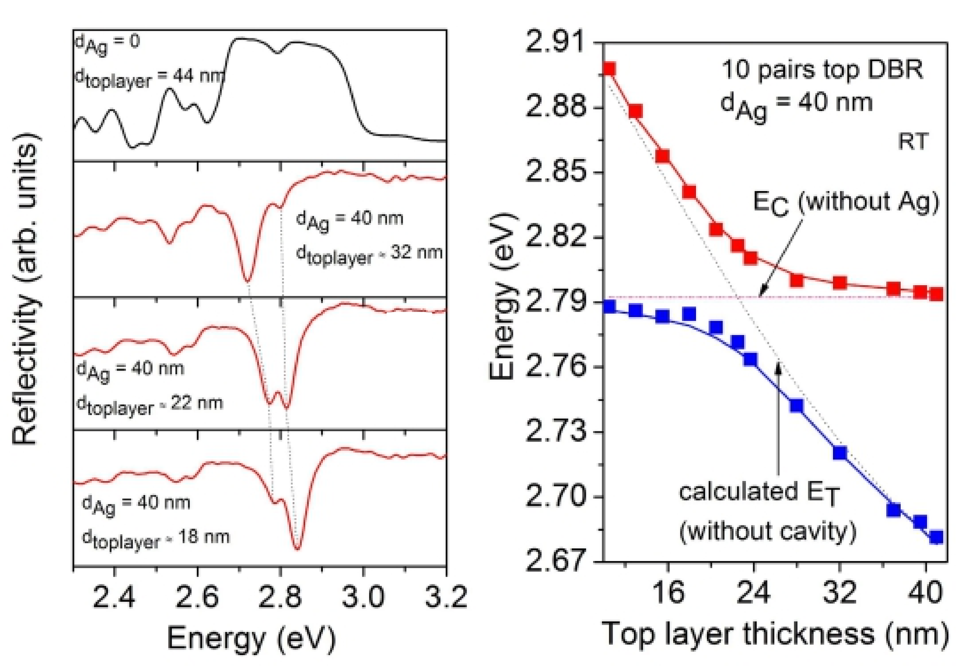
Strong coupling at low T

E_{FWHM}=2.5 meV at 4 K

E_{FWHM}=36 meV at 300K

→ No strong coupling at RT

Interaction of Tamm and cavity mode



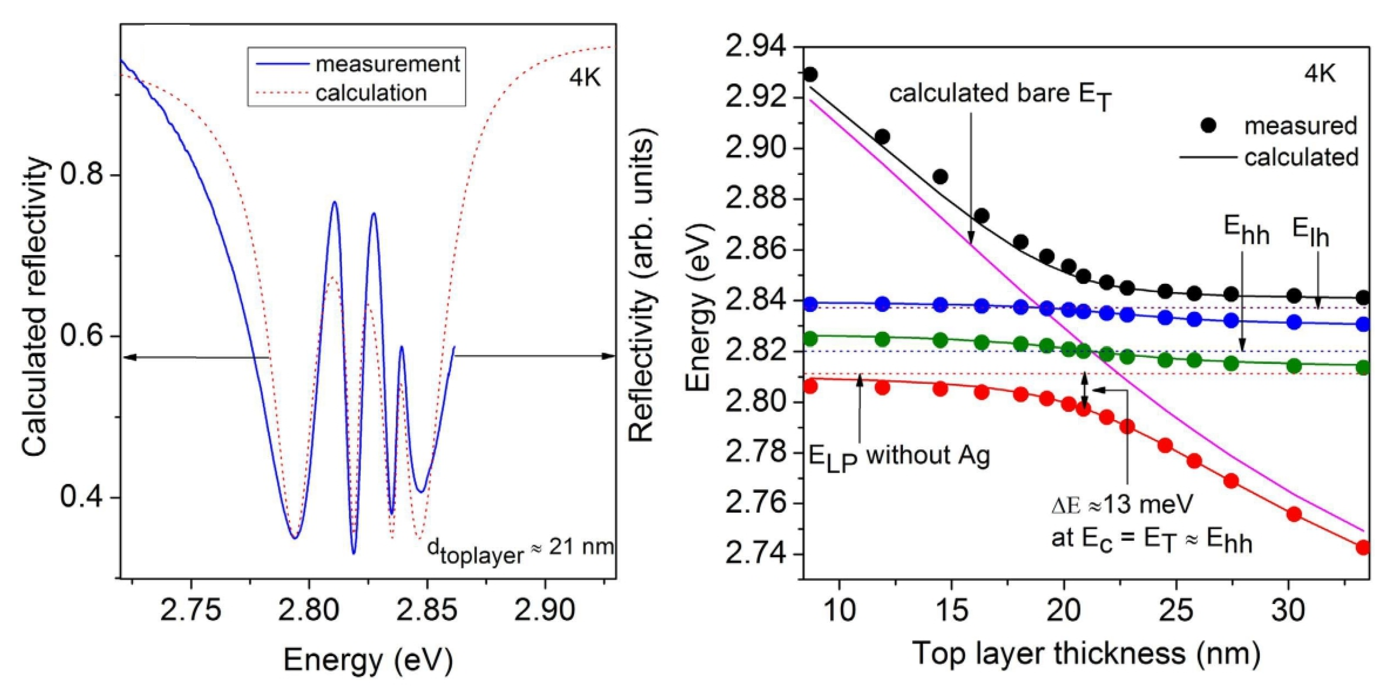
Reflectivity of sample without and with Ag layer for different top layer thicknesses

Ag-layer causes an additional reflectivity minimum due to Tamm polariton mode

Anticrossing is observed between the Tamm and cavity mode at RT

Splitting energy ~44 meV

Influence of Ag-layer - Hybrid state of TP exciton-polariton



Four resonances are observed due to the coupling of cavity, X_{hh}, X_{lh}, and TP resonances

Measured results are in excellent agreement with a four coupled-oscillators model calculation

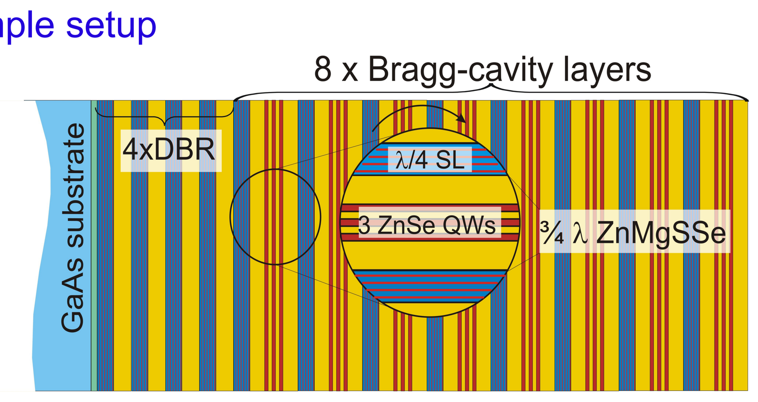
Total splitting LP – UP: 50 meV

→ increase by a factor of 1.7

SK S. Rahman et al., published in Scientific Report 2016

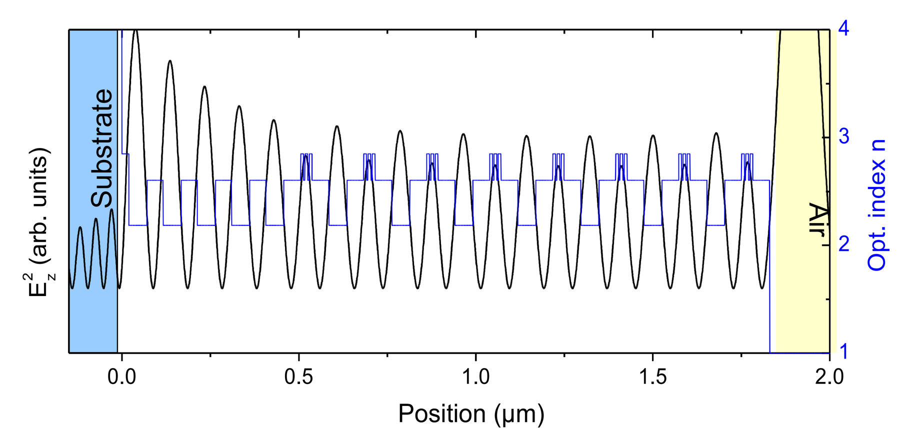
Bragg-polariton sample design

Sample setup



MBE grown sample

Calculated E-field distribution



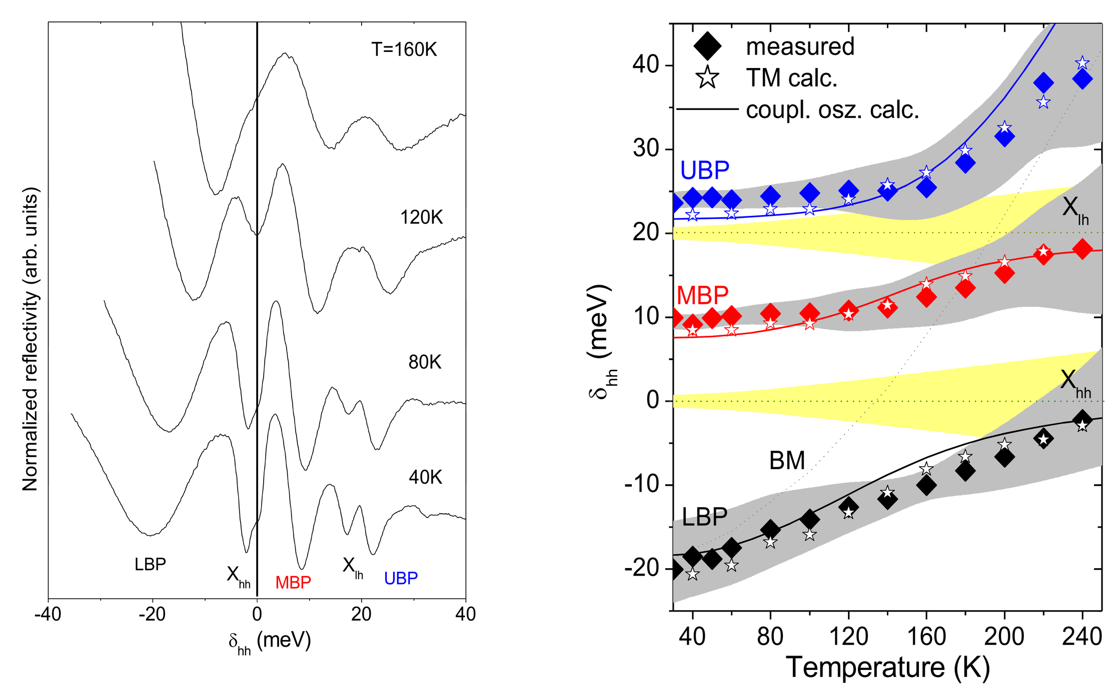
Advantage of unfolded microcavity:

Number of interfaces can be reduced from ~1,300 (conventional II-VI MC) down to ~500

- reduction of origin of stacking faults

- Electric field distribution is calculated for the 1st Bragg mode (BM)
- QWs are located at the field maximum of the BM
  - light-matter interaction between QWs and BM

Anticrossing observed by temperature dependent detuning



- Coupled oscillator and TM calculation considering excitonic spectral shift and change of refractive index, TM in addition line broadening
- Shaded region: measured polaritonic and calculated excitonic linewidth

X_{hh}/BM crossing point around 140 K indicated by spectral narrowing of LBP

- Spectra vertically shifted
- Relative energy position of X_{hh} is taken as zero
- Lower-, middle- and upper Bragg polariton branch (LBP, MBP, UBP) show spectral shift relative to X_{hh}

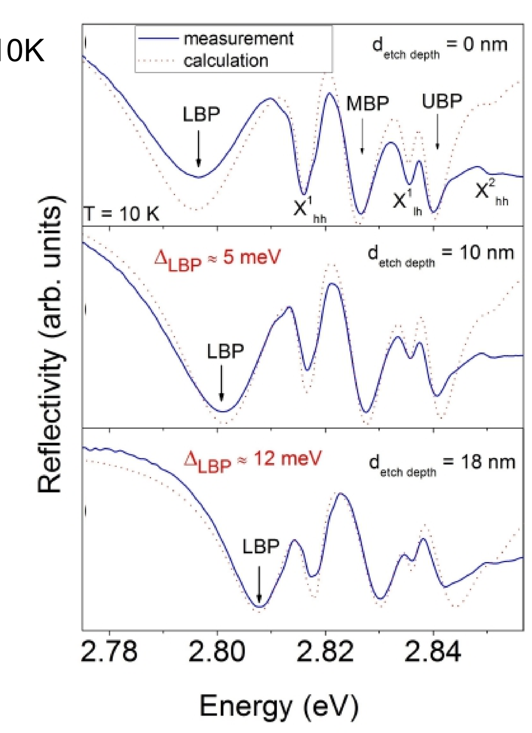
At X_{hh}/BM crossing point

$\hbar\Omega_{hh}$=(23±1) meV, $\hbar\Omega_{lh}$=(13±1) meV

Strong coupling regime up to 200 K

K. Sebald et al., APL **108**, 121105 (2016)

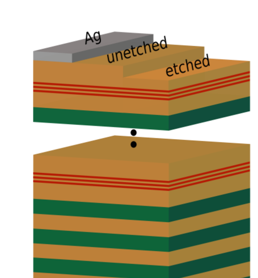
Tunable Bragg polaritons in hybrid structure

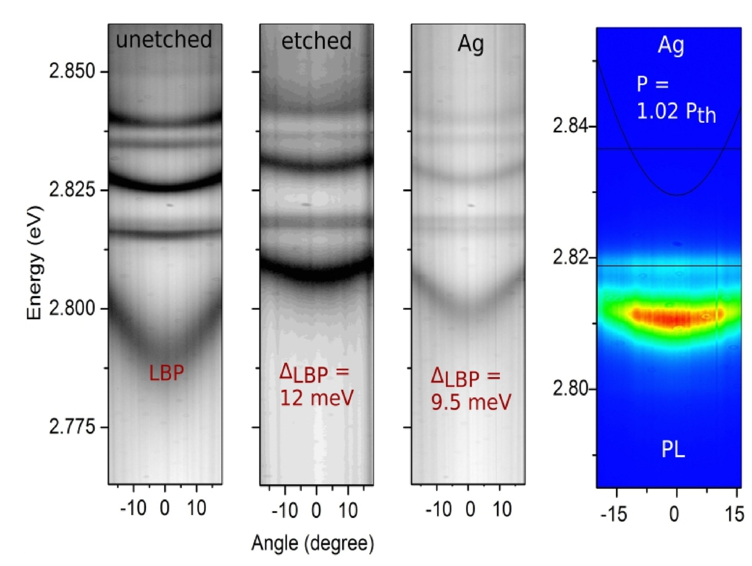


Spectral shift of the Bragg polaritons with change of the top layer thickness

Sample setup: thickness gradient of the top layer etched by CAIBE

15 nm of Ag are deposited





Angle resolved reflectivity and PL of Bragg polaritons modified by 18 nm reduced top layer thickness or 15 nm deposited Ag – pronounced spectral shift

→ possible realization of lateral potential traps for Bragg polaritons

Summary

Metal layers supporting Tamm plasmons show strong influence on cavity resonance
→ Tunability of cavity and TM resonance is realized

Strong coupling achieved with a simple sample configuration using TP and excitons
→ Promising for electrically tunable polariton devices

- Strong coupling in unfolded cavity with eight times three ZnSe quantum wells
- Coupling of Bragg mode with X_{hh} and X_{lh} results in three polariton branches
- Anticrossing was observed under temperature and layer-thickness variation
- Experimental findings coincide with theoretical calculations
- Strong coupling can be traced up to 200 K

➔ ZnSe-based Bragg polariton samples are promising to realize strong coupling near room temperature with a rather simple sample configuration

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[1] K. Sebald et al. Appl. Phys. Lett. **100**, 161104 (2012).
[2] S. Klembt et al. Appl. Phys. Lett. **100**, 121102 (2012).
[3] K. Sebald et al. Eur. Phys. J. B 84, 381 (2011).
[4] T. Klein et al. Appl. Phys. Lett. 107, 071101 (2015).