Annual Exam for PhD students
First Year

October 17, 2019

Nicola Melchioni
Supervisor: Alessandro Tredicucci

First Year Classes and Exams

Nanostructured Materials

Seminar: "ARPES study of Graphene highlights quasiparticle dynamics"

Given on July 25, 2019

Seminars on Condensed Matter

Seminar: "Klein Tunneling in Graphene: theory and experiments"

Given on October 11, 2019

Physics of Nanostructures

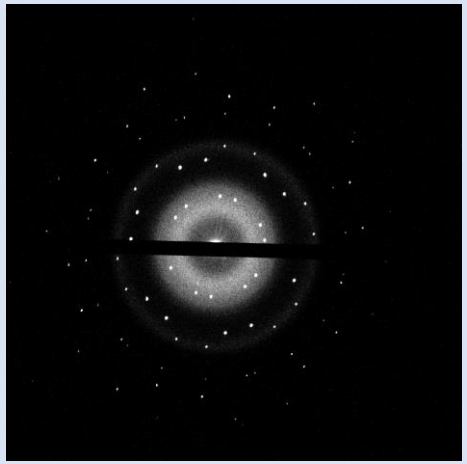
Seminar:"Manipulating Quantum Hall Channels: from non-equilibrium states to energy relaxation"

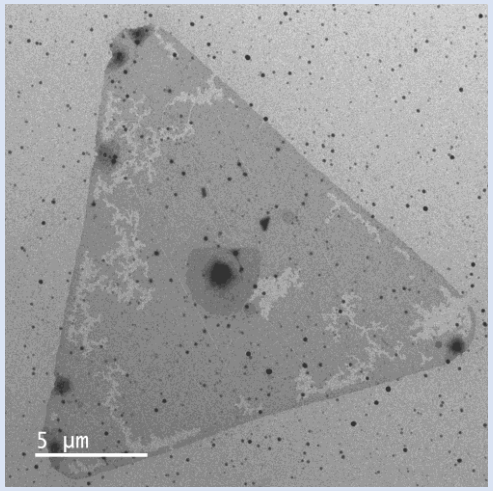
Given on October 14, 2019

Theory of Many Body Systems

Exam not given

Stages



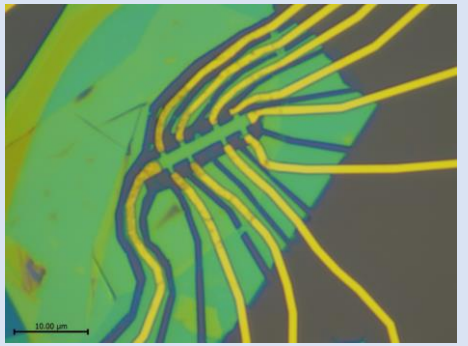


Stage in Dr. Mauro Gemmi's Group
Transmission Electron Microscopy

- Introduction to TEM
- TEM on a crystal structure
- TEM on biologic samples
- Data analysis: reconstruction of Ewald Sphere

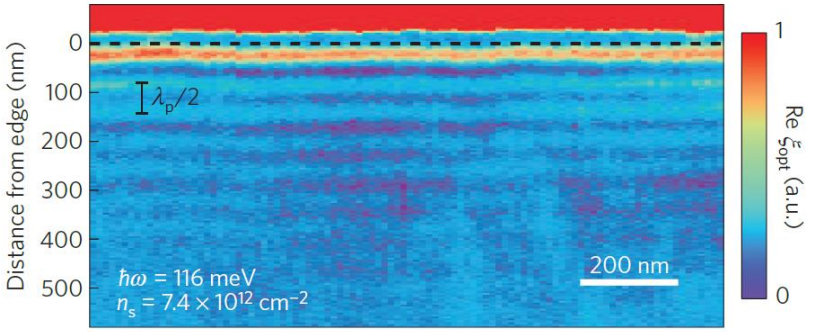
Stage in Dr. Francesco Rossella's Group
Low Temperature Magnetotransport

- Theoretical introduction
- The working of a cryostat with Heliox Insert
- Condensation of ^{3}He to reach sub-K temperatures
- Measurements on 2D systems (bilayer graphene)



Device from C.Coletti group, IIT

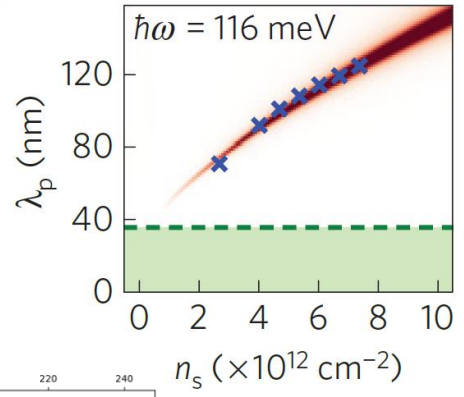
Introduction

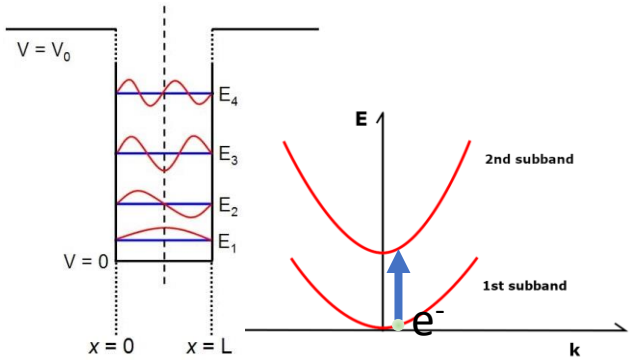


Graphene plasmons

- Tunable dispersion: $E_F \propto \sqrt{n} \rightarrow \lambda_{pl} \propto \sqrt{n}$
- Large confinement factor $\eta_0 \sim 10^2$
- Long propagation length

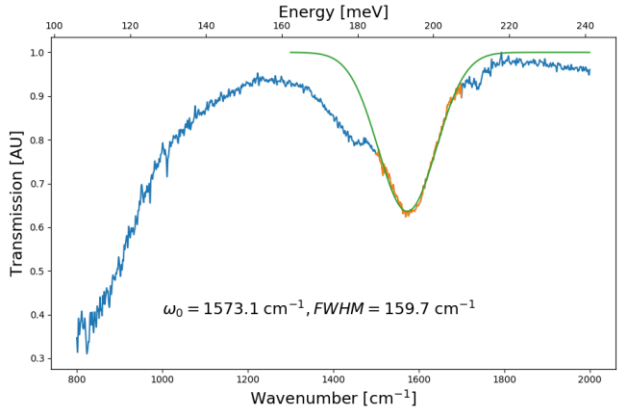
Woessner *et al*, *Nat Mat 2015*





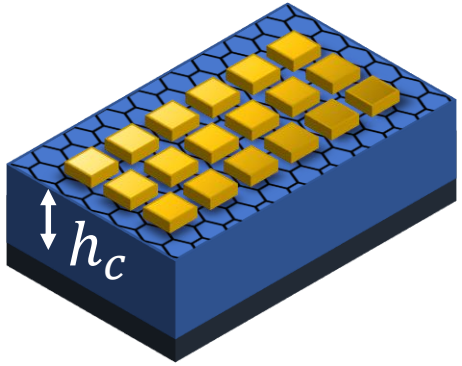
Intersubband transitions

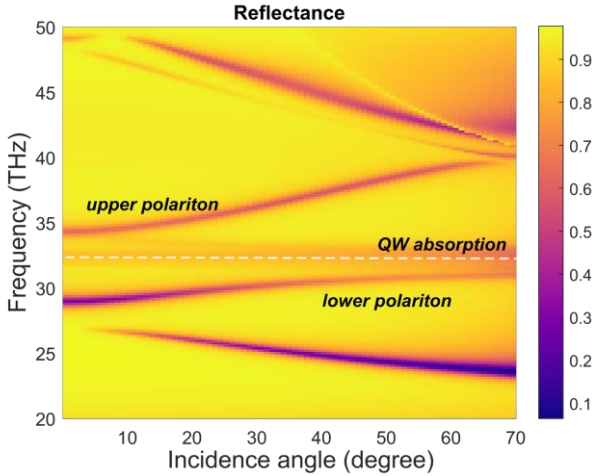
- Delta like linewidth
- III-V heterostructures
- Recently observed in 2D materials



Critical coupling

Cavity effect





Strong coupling

Resonant effect

Far Field measurements

1) Observing critical coupling of graphene plasmons

Plasmons excited by an array of gold nanoantennas

Resonance expected for $h_c \sim \lambda/4$

Expected to work for relatively low graphene mobility

Observe tunability with E_F as a hallmark of graphene impact

2) Putting a Quantum Well in the substrate

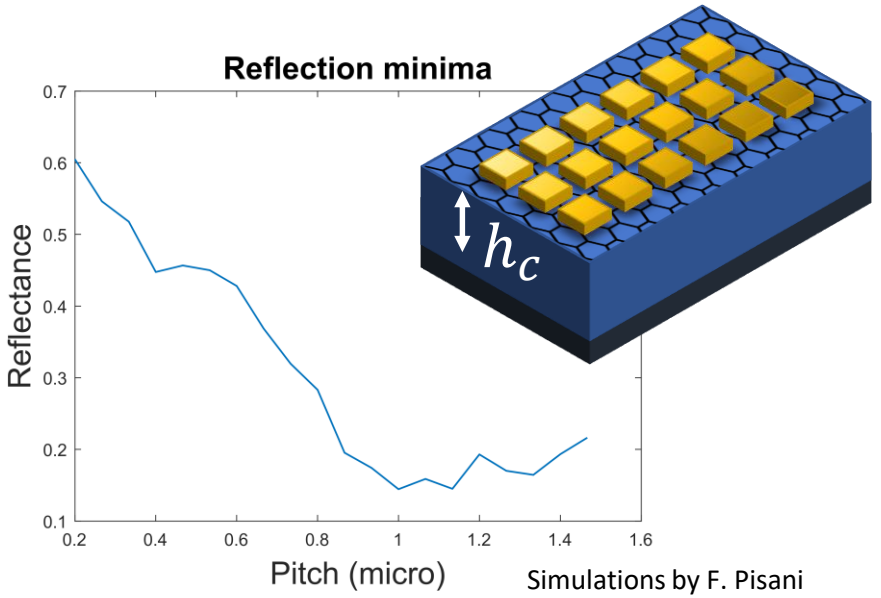
Strong coupling expected between ISB mode and plasmons

Increased absorption due to field confinement

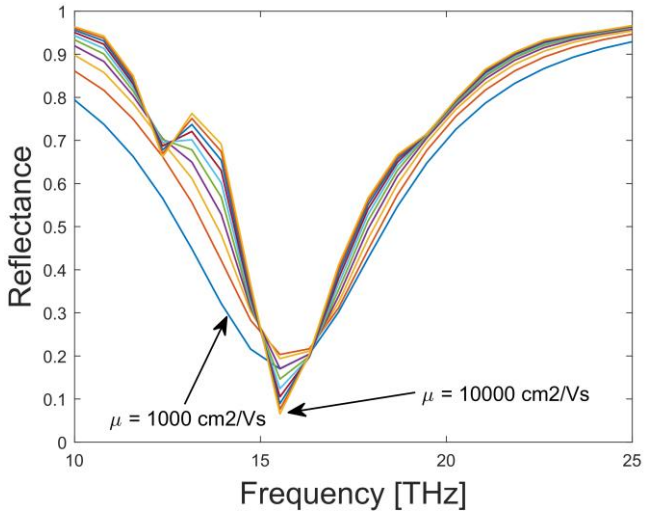
3) Outlook

Ultra strong coupling and vacuum oscillation

Tunable polaritonic laser



Simulations by F. Pisani



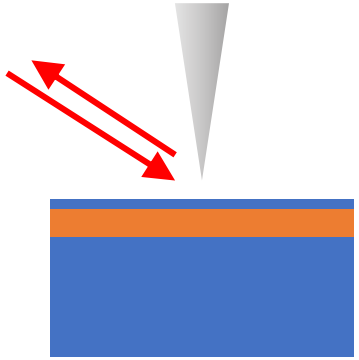
Near Field measurements

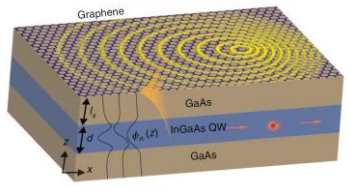
In collaboration with Frank Koppens' group (ICFO, Barcelona)

1) Near field Optical Spectroscopy of a III-V QW

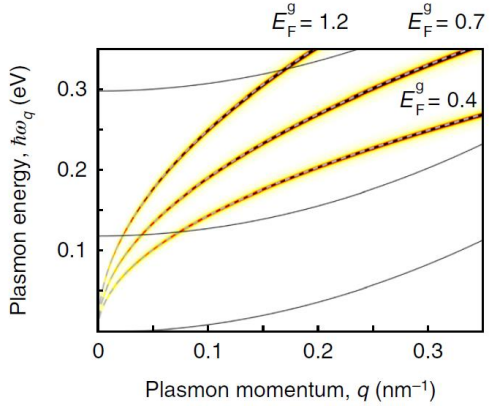
How does the transition line change if the QW interacts with a tip?

Can we measure the fluctuation of thickness?





Kurman *et al*, *Nat Phot 2018*



2) Near field Optical Spectroscopy of a QW with graphene

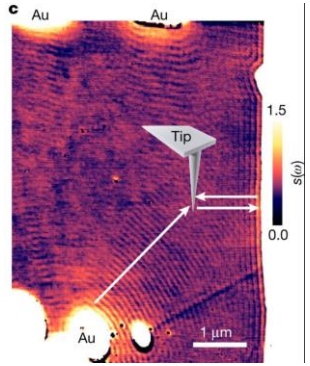
Can we observe coupling between the two excitations?

Can we induce non-vertical intersubband transitions?

3) Going to low T and using fully 2D structures

Increased performances due to low temperature

Increased coupling due to close spacing in the heterostructure



NEST
SCUOLA NORMALE SUPERIORE PISA

Thank you for your attention!