



GHOST

group of high resolution optical spectroscopy and related techniques

website: <http://ghost.fisica.unipg.it/>



Nanomagnetism Group

STAFF

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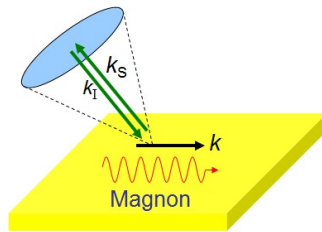
Gianluca Gubbiotti, CNR-IOM gubbiotti@iom.cnr.it

Silvia Tacchi, CNR-IOM tacchi@iom.cnr.it

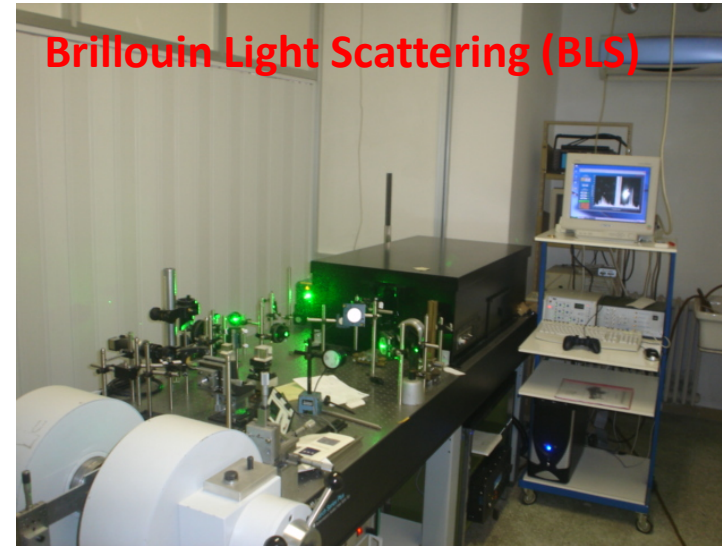
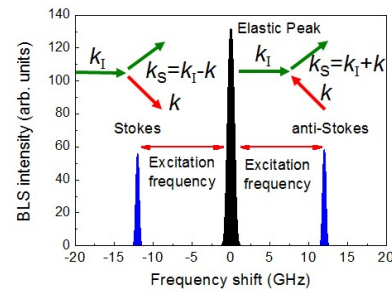
PhD STUDENTS

Raffaele Silvani, Dipartimento di Fisica e Geologia, PhD student

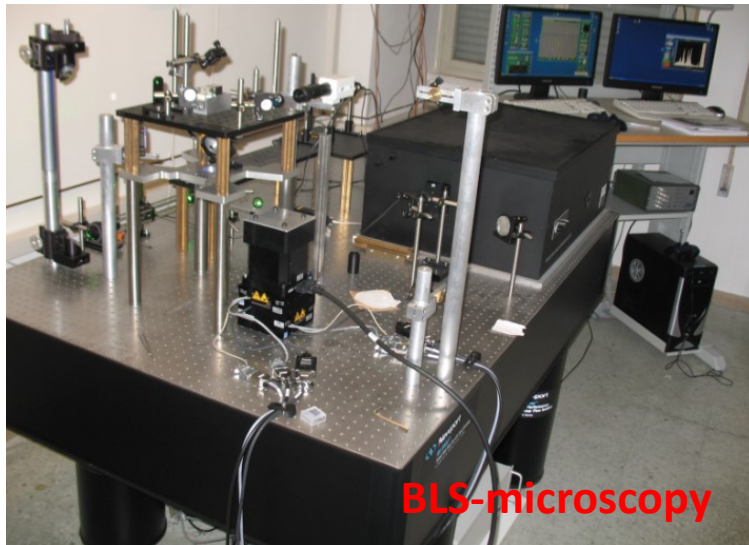
I nostri strumenti di indagine:



(inelastic scattering of photons by spin waves "magnons")

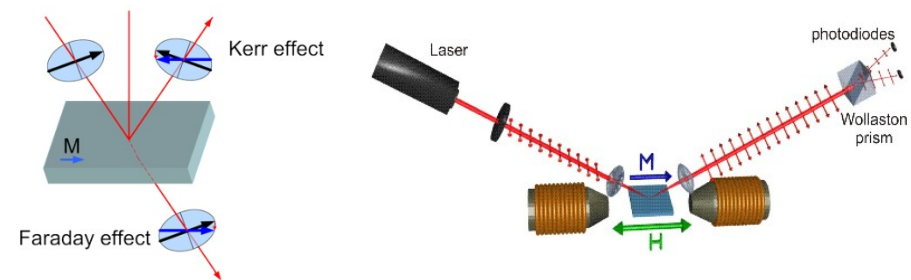


Brillouin Light Scattering (BLS)



BLS-microscopy

Magneto-Optic Kerr Effect (MOKE)



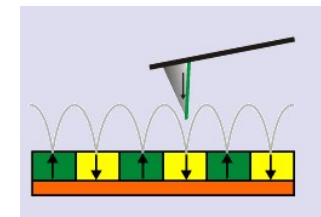
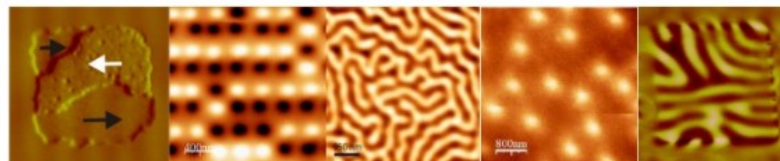
Micromagnetic simulations:

OOMMF

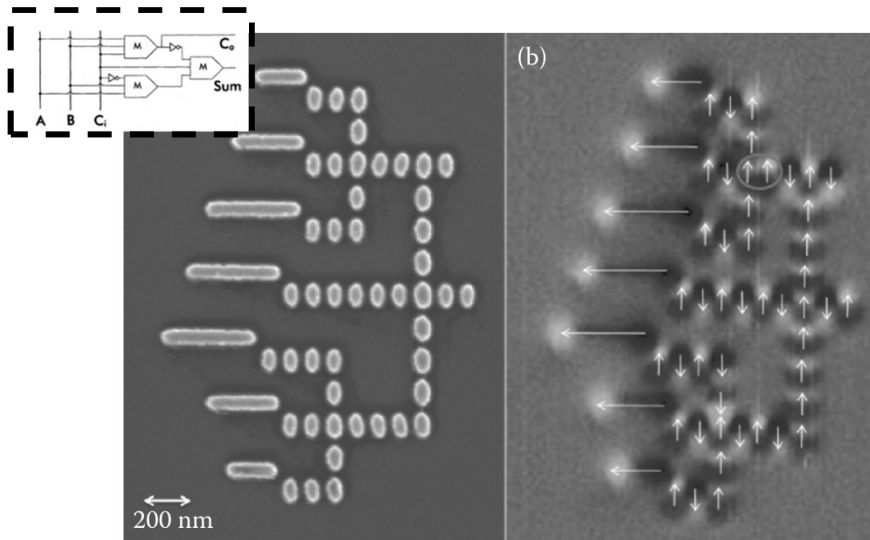
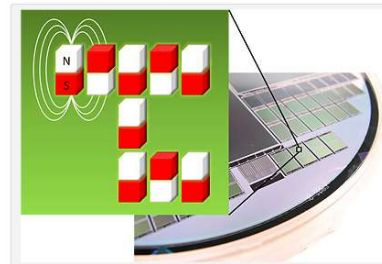
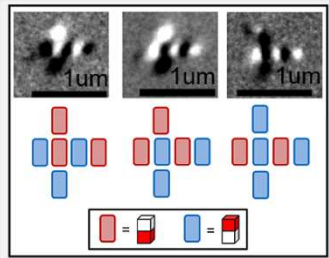
Micromagus

Mumax3 (GPUs, Nvidia CUDA®)

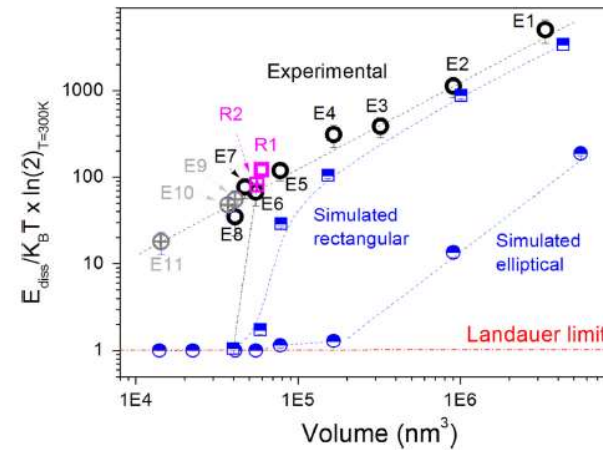
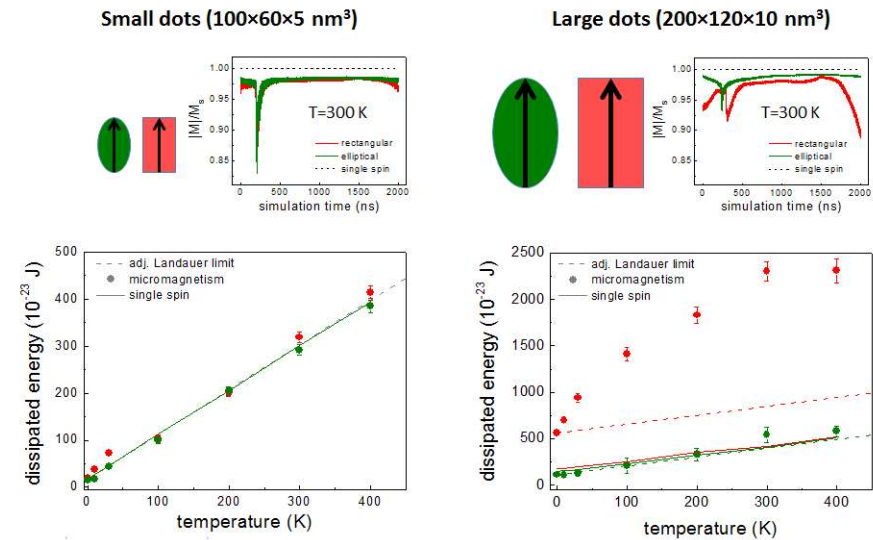
Magnetic Force Microscopy (MFM)



NanoMagnetic Logic (NML): costruire porte logiche usando nanomagneti.



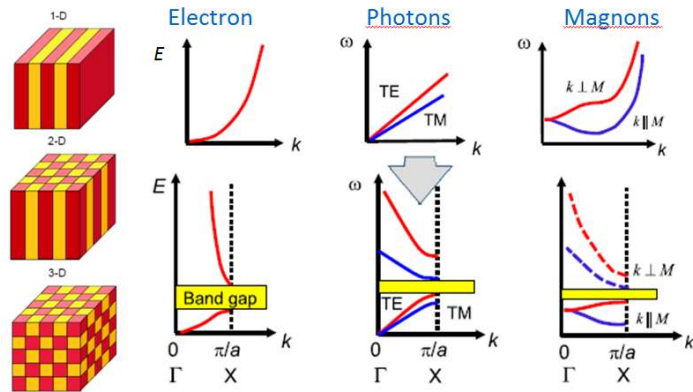
Energy dissipation during logic operations



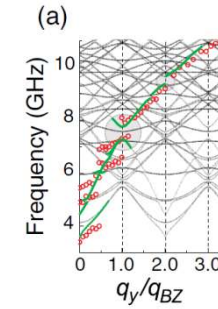
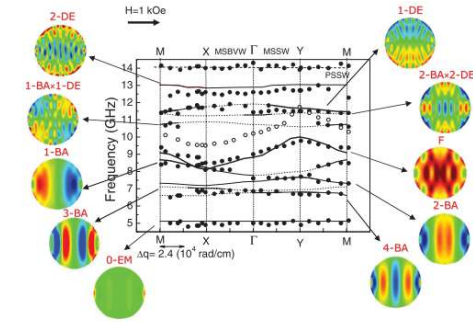
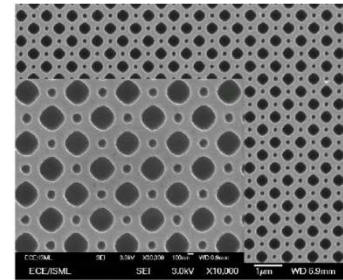
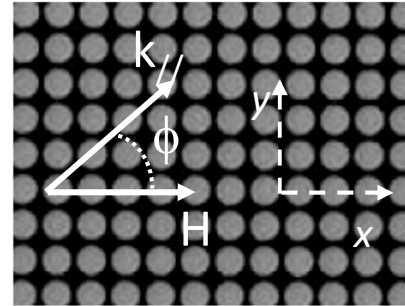
Collaborazione con: **Università di Wurzburg (Germania)**
Università di Notre-Dame (IN, USA)
CIC nanoGUNE (Spagna)

<p>Argomento</p>	<p>Studio del funzionamento di switch nanomagnetici e porte logiche in presenza di rumore termico (Triennale/Magistrale)</p>
<p>Tipo</p>	<p>Simulazioni (micromagnetismo GPU based) – Sperimentale (VMOKE)?</p>
<p>Descrizione</p>	<p>Studiare i <u>limiti energetici fondamentali</u> di funzionamento di singoli BIT e di porte logiche, sotto forma di nanomagneti o array di nanomagneti interagenti, in presenza di rumore termico. (<u>Nanomagnetic logic</u>)</p>
<p>Collaborazioni</p>	<ul style="list-style-type: none"> • Laboratorio NiPS (Perugia) • CIC Nanogune (Basque Country, Spain)
<p>Referente</p>	<p>Dr. Marco Madami (marco.madami@unipg.it)</p>
<p>Sistemi studiati Nanostrutture magnetiche (NiFe)</p>	<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div data-bbox="846 1107 1025 1203" style="border: 1px solid black; padding: 2px;"> </div> <div data-bbox="929 1125 1473 1497"> </div> <div data-bbox="1512 1129 2018 1490"> </div> </div>

Magnonica: studio della propagazione di onde di spin (**cristalli magnonici**)

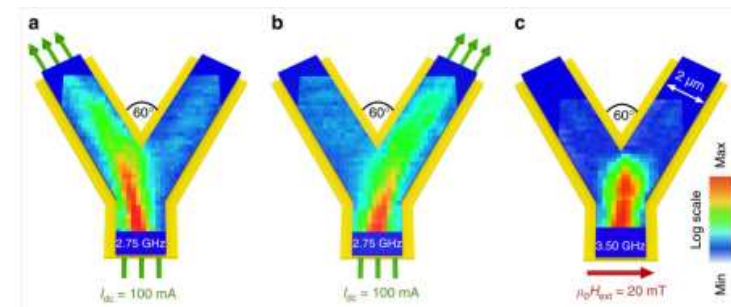
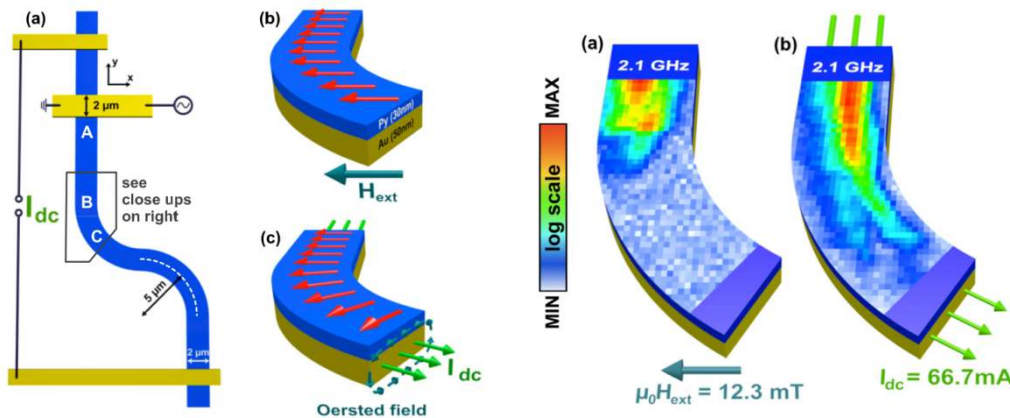


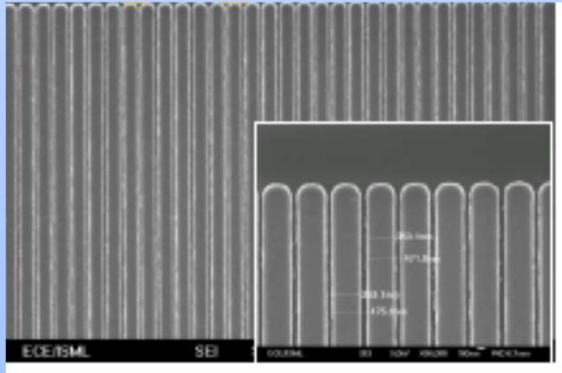
Cristallo magnonico: **modulazione periodica** delle proprietà magnetiche



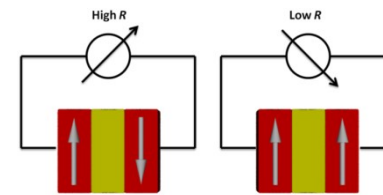
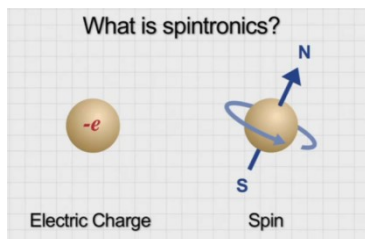
2D: Matrici bi-dimensionali di **dots** e **antidots**

SPIN WAVE LOGIC (SWL): Codificare, trasportare ed elaborare l'informazione con onde di spin ?



Argomento	Studio della propagazione di onde di spin in cristalli magnonici unidimensionali (Triennale)
Tipo	Sperimentale (BLS) – Simulazioni (micromagnetismo)
Descrizione	Misura della <u>struttura a bande</u> in cristalli magnonici 1D. Comprensione dei fattori (geometria, disposizione) che determinano la formazione delle band gap in matrici di nanowires. (Cristalli magnonici)
Collaborazioni	<ul style="list-style-type: none"> • Information Storage Materials Laboratory, National University of Singapore • University of Western Australia, Perth
Referente	Dr. Gianluca Gubbiotti (CNR-IOM) (gubbiotti@iom.cnr.it)
Sistemi studiati Matrici di barre con diversa separazione	 <p>The image shows a scanning electron microscope (SEM) view of a nanowire array. The main image displays a dense array of vertical nanowires. An inset in the bottom right corner provides a magnified view of the nanowires, showing their rounded tops and the gaps between them. Labels in the inset indicate dimensions: 200 nm, 100 nm, and 50 nm. The SEM parameters at the bottom of the image are: EDC/ISML SEI VOL:10.0kV X10.0k X-Y-Z: 10.0um 10.0um 10.0um PCL: 1.0um.</p>

Spintronics: sfruttare lo **spin** degli elettroni oltre che la loro **carica elettrica**

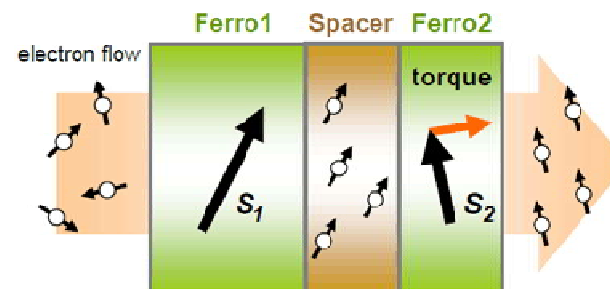


1988: Giant magnetoresistance (**GMR**) – Nobel Prize 2007

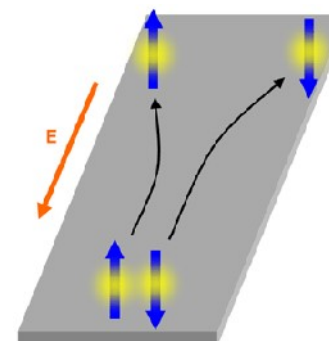
Spintronics (Spin + Charge)



1996-1999: Spin-Transfer Torque (STT)



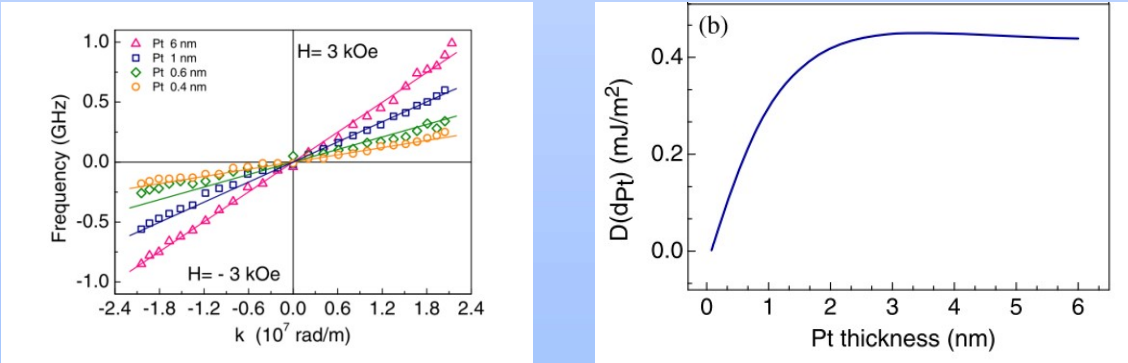
1971-2004: Spin-Hall effect (SHE)



Applications

<p>HDD (Hard Disc Drive) Read head</p> <p>GMR</p> <p>Large TMR + Low R Large CPP-GMR</p>	<p>MRAM (Magnetic Random Access Memory)</p> <p>M. Johnson, <i>IEEE Spectrum</i> 37, 33 (2000).</p> <p>Huge TMR</p>	<p>Spin-FET (Spin - Field Effect Transistor)</p> <p>FM1 Semiconductor FM2</p> <p>S. Datta and B. Das, <i>Appl. Phys. Lett.</i> 56, 665 (1990).</p> <p>High spin injection efficiency into semiconductor</p>
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- TMR : Tunnel Magnetoresistance
- CPP-GMR : Current Perpendicular to Plane- Giant Magnetoresistance

Argomento	Studio dell'interazione Dzyaloshinskii-Moriya in eterostrutture del tipo materiale ferromagnetico/metallo pesante (Triennale/Magistrale)
Tipo	Sperimentale (BLS) – Simulazioni (micromagnetismo)
Descrizione	Misura dell'interazione <u>Dzyaloshinskii-Moriya</u> (DMI) in film ferromagnetici sottili in contatto con film di metalli pesanti. Studio dell'effetto della DMI sulla propagazione delle onde di spin in cristalli magnonici attraverso simulazioni micromagnetiche. (Cristalli magnonici - Spintronica)
Collaborazioni	<ul style="list-style-type: none"> Istituto Nazionale di Ricerca Metrologica (INRIM), Politecnico di Milano, Gothenburg University
Referente	Dr. Silvia Tacchi (CNR-IOM) (tacchi@iom.cnr.it)
<p>Sistemi studiati</p> <p>Eterostrutture del tipo</p> <p>Pt/CoFeB</p>	 <p>Figure (a) shows the Brillouin-Light Scattering (BLS) dispersion curves for Pt/CoFeB heterostructures with Pt thicknesses of 6 nm (red triangles), 1 nm (blue squares), 0.6 nm (green circles), and 0.4 nm (orange diamonds). The x-axis is the wave vector k in units of 10^7 rad/m, ranging from -2.4 to 2.4. The y-axis is Frequency in GHz, ranging from -1.0 to 1.0. Two sets of curves are shown for magnetic fields $H = 3$ kOe and $H = -3$ kOe. The curves show a clear splitting and shift of the magnon modes as a function of Pt thickness and magnetic field.</p> <p>Figure (b) shows the Dzyaloshinskii-Moriya interaction (DMI) parameter $D(d_{Pt})$ in mJ/m^2 as a function of Pt thickness in nm. The x-axis ranges from 0 to 6 nm, and the y-axis ranges from 0.0 to 0.4 mJ/m^2. The curve shows that the DMI parameter increases rapidly from 0 at 0 nm and saturates at approximately 0.45 mJ/m^2 for Pt thicknesses greater than 3 nm.</p>

Argomento	Studio sperimentale di risuonatori ad onde acustiche di volume (BAW) e di superficie (SAW) (Triennale)
Tipo	Sperimentale (microspettroscopia BLS)
Descrizione	Mappatura bidimensionale, tramite micro-spettroscopia BLS delle proprietà di emissione di risuonatori ad onde acustiche di volume (BAW) e di superficie (SAW) per applicazioni in dispositivi per telecomunicazioni.
Collaborazioni	<ul style="list-style-type: none"> • QORVO (multinazionale produttrice di componenti RF)
Referente	Prof. Giovanni Carlotti (giovanni.carlotti@unipg.it)
<p>Sistemi studiati</p> <p>Risuonatori ad onde acustiche di volume (BAW) e superficie (SAW)</p>	