"International Summer School on Ultrasonic and Piezoelectric Sensors" *Final program at a glance*			
Day 1	**22 July 2020**	**Start time 8.45(CEST)**	**End time 18.00 (CEST)**
Lorenzo Capineri	Opening	8.45	9.00
Vittorio Ferrari (Fundamental Background)	Fundamentals of Piezoelectricity	9.00	11.00
Antonio Iula	Wideband Ultrasonic Piezoelectric Transducer Modelling	11.00	12.00
Stefano Ricci	Doppler methods for ultrasonic applications	12.00	13.00
Lunch Break			
Piero Tortoli (Keynote Speaker)	Ultrasonic Systems for Biomedical Applications	15.00	17.00
Enrico Boni – Alessandro Ramalli	Experimental demo #1: Standard and advanced modes for biomedical Ultrasound imaging.	17.00	18.00
Day 2	**23 July 2020**	**Start time 9.00(CEST)**	**End time 19.00(CEST)**
Maurizio Valle	Interface electronics for piezoelectric polymeric sensors.	9.00	11.00
Massimo De Vittorio	Flexible Piezoelectric Technologies for Energy Harvesting and Health Monitoring	11.00	13.00
Lunch Break			
Maurizio Valle	Pressure and tactile sensor systems (artificial electronic skin) based on piezoelectric polymeric sensors.	15.00	16.00
Vittorio Ferrari	Applications in Transducers and Energy Harvesting	16.00	17.00
Andrea Bulletti	Experimental demo #2: Beamforming using Airborne Ultrasonic Transducers and a microcontroller unit board.	17.00	19.00
Day 3	**24 July 2020**	**Start time 9.00CEST)**	**End time 19.15(CEST)**
Lorenzo Capineri	Piezopolymer Interdigital transducers (IDT) for ultrasonic guided waves: modelling, fabrication technologies, and electronic front end	9.00	11.00
Luca De Marchi	Ultrasound signal processing in guided waves inspections.	11.00	13.00
Lunch Break			
Antonio Iula	Ultrasound systems for biometric recognition	15.00	16.00
Riccardo Carotenuto	Ultrasonic Positioning Systems	16.00	17.00
B. (Pierre) T. Khuri-Yakub (Keynote speaker)	Capacitive Micromachined Ultrasonic Transducers (CMUTs): From an idea to commercialization	17.00	18.00
Alessandro Stuart Savoia	MEMS Ultrasonic Transducers: Operating Principles and Applications	18.00	19.00
Lorenzo Capineri	**Final test delivery and Closing Remarks**	**19.00**	**19.15**

"International Summer School on Ultrasonic and Piezoelectric Sensors" *Final program with abstracts*			
Day 1	**22 July 2020**	**Start time 8.45(CEST)**	**End time 18.00 (CEST)**
Lorenzo Capineri	**Opening**	**8.45**	**9.00**
Vittorio Ferrari	**Fundamentals of Piezoelectricity**	**9.00**	**11.00**
Starting from a historical overview on its origin, the piezoelectric effect is introduced as a cross-field conversion mechanism between the electrical and mechanical domains. The constitutive equations in rigorous notation are presented, yet the treatment aims at an intuitive understanding of the involved principles. A review on the piezoelectric materials is offered from the viewpoint and needs of a device designer and system user. The modelling of piezoelectric elements is then discussed based on the electromechanical analogy in order to describe, within a unified framework, both the behavior of devices and the coupling with electronic circuitry.			
Antonio Iula	**Wideband Ultrasonic Piezoelectric Transducer Modelling**	**11.00**	**12.00**
Wideband ultrasonic transducers that exploit the piezoelectric effect have been used for generating ultrasound imaging in many applications that include medical diagnostic and non destructive evaluation. The talk starts with a description of the general equations of piezoelectric materials, highlighting their complexity and discussing how they can be simplified to provide analytical solutions for some particular one-dimensional geometries. For one of such geometry, the thin disk, a complete model will be derived and some simulations of the Electric Impedance and of the Transmission and Receiving Transfer Functions will be carried out and the results discussed. The criterion for designing a wideband transducer by adding opportune elements to the narrowband piezoelectric element will be finally described and simulations of such a transducer performed.			
Stefano Ricci	**Doppler methods for ultrasonic applications**	**12.00**	**13.00**
Ultrasonic Doppler methods are employed in biomedical and industrial applications for their capability of accurately detecting moving targets. The measure of the velocity of the blood flowing in vessels, the visualization of the complex blood vortexes present in the heart, the characterization of the rheology of fluids and suspensions moving in industrial pipes, represent some of the outcomes of the Doppler ultrasound techniques. In this lecture, the main methods employed for the acquisition and the processing of the Doppler signal are reviewed and detailed. Continuous and Pulsed Wave methods are described together with their limitations and critical issues. Some of the latest challenges, like those related to the estimate of the flow direction, are mentioned and some solution is illustrated.			
Lunch Break			
Piero Tortoli (Keynote Speaker)	**Ultrasonic Systems for Biomedical Applications**	**15.00**	**17.00**
After a brief historical overview of the past major developments in the field of medical ultrasound, the architecture of modern electronic scanners is described, and the general characteristics of the transmit, receive and acquisition circuits are reported. The second part of this lecture is dedicated to the description of imaging and Doppler methods typically implemented in commercial scanners. Finally, the main features of the so-called "open scanners" are discussed, and the contribution of these scanners to the development of advanced imaging/Doppler methods is highlighted.			
Enrico Boni – Alessandro Ramalli	**Experimental demo #1: Standard and advanced modes for biomedical Ultrasound imaging.**	**17.00**	**18.00**
The demonstration will be based on the advanced ultrasound open platform (ULA-OP 256), developed by the University of Florence, which allows testing both standard and advanced imaging modes. A short description of the architecture of the ULA-OP 256 system will be provided. A brief introduction to standard B-mode and pulsed wave Doppler imaging will then be followed by a demo on high frame rate applications, vector Doppler, and 3-D imaging.			

Day 2	23 July 2020	Start time 9.00(CEST)	End time 19.00 (CEST)
Maurizio Valle	**Interface electronics for piezoelectric polymeric sensors.**	**9.00**	**11.00**
Basic features of piezoelectric polymeric materials such as PVDF and P(VDF-TrFE) and their electrical (e.g. SPICE) models will be introduced: the electro-mechanical models of the transducers and the interface electronic circuit solutions will be presented in a synergic way. The lecture will address interface electronics implementations (e.g. Charge/Voltage amplifiers) and microelectronic devices e.g. Piezoelectric-Oxide-Semiconductor-Field-Effect-Transistor POSFET devices either on silicon or on flexible substrates implemented with organic semiconductors.			
Massimo De Vittorio	**Flexible Piezoelectric Technologies for Energy Harvesting and Health Monitoring**	**11.00**	**13.00**
This talk will present recent advances on biocompatible, flexible and compliant piezoelectric thin film devices applied to energy harvesting and to monitor health parameters on the human body. The technology of biocompatible aluminium nitride based piezoelectric on polymeric substrate will be shown to be effective for the fabrication of transducers to convert the mechanical energy of water flow and wind in electrical energy and for the production of ultra-sensitive piezoelectric smart patches for cardiovascular monitoring.			
Lunch Break			
Maurizio Valle	**Pressure and tactile sensor systems (artificial electronic skin) based on piezoelectric polymeric sensors.**	**15.00**	**16.00**
Distributed pressure sensing systems based on arrays of piezoelectric polymeric transducers will be introduced. The lecture will focus on two different examples: i) tactile sensing silicon chips based on POSFET devices; ii) arrays of screen printed transducers on flexible substrates. Aspects related to the embedded implementation of algorithms and methods for the extraction of meaningful information from raw data will be assessed.			
Vittorio Ferrari	**Applications in Transducers and Energy Harvesting**	**16.00**	**17.00**
The exploitation of the piezoelectric effect in signal transduction and energy conversion is discussed. Examples of piezoelectric sensors, actuators, and MEMS for different purposes and of energy harvesters are presented. In particular, acoustic-wave devices, resonant sensors and microbalances are described together with dedicated electronic interface circuits and techniques for wired and contactless signal readout. Also, examples of techniques and devices for piezoelectric energy harvesting from vibration and motion are reported, intended for powering battery-less sensors and microsystems in industrial and wearable applications.			
Andrea Bulletti	**Experimental demo #2: Beamforming using Airborne Ultrasonic Transducers and a microcontroller unit board.**	**17.00**	**19.00**
The laboratory activity is aimed to demonstrate how constructive and destructive interference enables the formation of beams around a four-element ultrasonic transducer array. The set-up is based on the Texas Instruments Analog System Lab Kit (ASLK) with four narrow-band airborne ultrasonic transducers with nominal central frequency of 40 kHz. The scope is the transmission/acquisition of an ultrasound signal in the air for measuring the distance of a target. The generation of the transmitting signals will be organized with a microcontroller unit board and the acquisition of signals reflected from the target will occur using a remote-controlled oscilloscope. The entire system will be managed using a PC with possibility of a remote access.			

Day 3	24 July 2020	Start time 9.00(CEST)	End time 19.15 (CEST)
Lorenzo Capineri	**Piezopolymer Interdigital transducers for ultrasonic guided waves: modelling, fabrication technologies, and electronic front end**	**9.00**	**11.00**
Interdigital transducers (IDT) are widely used to excite and receive guided ultrasonic waves in plate-like materials. For Non-Destructive Testing (NDT) and Structural Health Monitoring (SHM) the IDT can be designed with the finger electrodes geometry to select the Lamb wave mode of interests. The dimensions and geometry of the fingers are related to the transducers characteristics as frequency response, sensitivity, directivity. The fabrication of IDT for the 50 kHz – 1MHz frequency range based on of piezoelectric film is of interest for the flexibility and the compliance to the target surface structure. Fabrication technologies for piezopolymer IDT are described for single transducer and for the array configuration. Finally, to overcome some of the inherent disadvantage of piezofilm material respect to piezoceramic the main characteristics of the connection to the analog front end will be described with electronic design examples.			
Luca De Marchi	**Ultrasound signal processing in guided waves inspections.**	**11.00**	**13.00**
The use of ultrasonic guided waves (GWs) for structural health monitoring (SHM) has interested many researchers. Nevertheless, Lamb-wave testing for SHM is complicated by the dispersive nature of wave modes, which deteriorates the wave spatial resolution and makes the experimental data hard to interpret. To tackle this problem, methods which analyze the dispersive signals in the domain spanned by time-frequency representations (TFRs) have been proposed. Such representations may be combined with the so-called compressive sensing (CS) theory, which offers an intriguing alternative with respect to the classical process of acquiring signals according to the Shannon–Nyquist paradigm. This combination naturally leads to super-resolved and artifact-free representations, even in noisy environments, and are particularly effective to extract the information on the wave distance of propagation. In this talk, a CS framework for Lamb wave acquisitions will be presented. It will be shown how this framework can minimize the number of ultrasonic scan point locations over the surface of the inspected medium while preserving and, to some extent, even enhancing the damage imaging capability.			
Lunch Break			
Antonio Iula	**Ultrasound systems for biometric recognition**	**15.00**	**16.00**
Biometric recognition systems are finding application in more and more civilian fields because they proved to be reliable and accurate. Among the other technologies, Ultrasound has the main merit of acquiring 3D images, which results in more distinctive features and resistance to spoof attacks. This talk reviews main research activities devoted to studying and developing ultrasound sensors and systems for biometric recognition purposes. Several transducer technologies and different ultrasound techniques have been experimented to image biometric characteristics like fingerprint, hand vein pattern, palmprint, hand geometry. Basic concepts on ultrasound imaging techniques and technologies are briefly recalled and, subsequently, research studies are classified by considering the kind of technique used for collecting the ultrasound image. Activities carried out in the Laboratory of Electronics and Ultrasound at the University of Basilicata in the last years are finally presented and discussed.			

Riccardo Carotenuto	**Ultrasonic Positioning Systems**	**16.00**	**17.00**
Positioning objects such as appliances inside rooms has become of fundamental importance in the Internet o Things (IoT) and in-home automation, as well as in augmented reality (AR). Tridimensional positioning with high spatial resolution opens new applications in the fields of IoT and domotics, as well as logistics and mobile asset management. Positioning of objects, like home or office assets, as well as people, is crucial for spatial-based control of operation. Many attempts to develop indoor positioning systems with sufficient resolution and reasonable cost have been reported in the literature, however still open questions are sufficient accuracy, low cost, miniaturization, and operation relying on small batteries. Proposed systems use a number of technologies including radio frequency signals, multiple cameras, lasers, infrared beams, magnetic sensors, and ultrasonic signals. Systems based on ultrasonic waves provide distances and spatial positions with a high degree of precision at a relatively low cost. Ultrasonic positioning systems (UPS) can be based on different architectures and technical solutions. Some of the developed systems and research results obtained at the University of Reggio Calabria will be presented.			
B. (Pierre) T. Khuri-Yakub (Keynote speaker)	**Capacitive Micromachined Ultrasonic Transducers (CMUTs): From an idea to commercialization**	**17.00**	**18.00**
The capacitive micromachined ultrasonic transducer (CMUT), in its present most widely used configuration, was first conceived in 1994. The last 26 years have seen international adoption, and its eventual commercialization in medical imaging, and possibly other applications in the future. This presentation will start with a brief introduction of the CMUT and its merits in comparison to other ultrasound transducers. Next, we will be summarize the various developments necessary to realize devices: theory (analytic solution, finite element modeling); technology (sacrificial release, direct bonding); modes of operation (conventional, pull-in, permanent pull-in); electronic integration (CMUT on ASIC, flip-chip on ASIC, interposer); packaging (backing, focusing lens); and system integration. Finally, we present a few examples of using CMUTs in airborne and immersion application, such as sensing and medical imaging.			
Alessandro Stuart Savoia	**MEMS Ultrasonic Transducers: Operating Principles and Applications**	**18.00**	**19.00**
The last few years have seen a rapid increase in academic and industrial research and development in the field of MEMS ultrasonic transducers. Capacitive and Piezoelectric Micromachined Ultrasonic Transducer (CMUT and PMUT) technologies are playing a fundamental role in the development of novel applications such as ultra-portable medical imaging systems and under-display fingerprint scanners. The key aspect here is the integration of the transducer and the front-end electronics, enabled by the enhanced compatibility between MEMS and standard integrated circuit technologies. The first part of this lecture will present a review of MEMS ultrasonic transducers operating principles and fabrication approaches, as well as application examples, highlighting the main advantages as compared to conventional piezoelectric ultrasonic transducers. The second part of this lecture will focus on the design, fabrication, characterization, and system integration of 1-D and 2-D MEMS ultrasonic transducer arrays for medical imaging applications.			
Lorenzo Capineri	**Final test delivery and Closing Remarks**	**19.00**	**19.15**