The origins of solid state physics in Italy: 1945 - 1960

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- The original audio interviews have been converted into the mp3 format. Some samples can be listened to on this page https://fisica.unipv.it/percorsi/doc.htm

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- The invention of the point-contact transistor by John Bardeen and Walter Brattain (1947) can be considered as the closing act of a half-century-long research on point-contact rectifiers and opened the way – theoretically traced by William Shockley – to the building of the p-n junction transistor (1952)

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- In 1960 Theodore Harold Maiman built the first (pulsed) solid state laser

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- The training of students who entered the course in Physics in the immediate post-war period was based on an out-of-date study plan established in 1937, which would remain in force until 1961.

Solid State Physics in Italy - General features

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- In the following, we shall draw a synthetic picture of the groups' geographical locations and their research.

The ‘Galileo Ferraris’ Institute, Turin

- The 'Galileo Ferraris' was born as a project of the Società Idroelettrica Piemonte, which, in March 1929, allocated ten million lire (equivalent to some 13.5 billion Lire of 2001). It risked being abandoned due to the significant economic crisis of that period. The joint intervention of the municipality of Turin and the State re-launched the project, and the Institute opened in 1935. University researchers (School of Electrical Engineering of the Polytechnic) and researchers hired on a fixed-term contract worked at the Institute.

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- In Solid State Physics, the contribution of Galileo Ferraris' Institute, in the period under review, was mainly in the field of magnetic properties of materials. Initially, the section was directed by Carlo Chiodi and Valentino Zerbini. In the post-war period, research on magnetic properties was carried out by Giorgio Montalenti (1915-1990) and coworkers. → Montalenti's interview by Silvana Galdabini and Giuseppe Giuliani (February 1, 1984).

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- The group of Pavia grew around the figure of Luigi Giulotto (1911-1986). Piero Caldirola (1914-1984) and Giulotto opened a happy and lasting season of collaboration. The two physicists (Giulotto experimentalist and Caldirola theorist) also wrote some papers. However, the nature of their collaboration, based on mutual esteem, was essentially characterized by discussions on "what to do?" "Caldirola"

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- Caldirola suggested to Giulotto to study the composite spectrum of the H_α line of the hydrogen atom and, later, to deal with the nuclear magnetic resonance.
- The challenging experiment on the H_α line started in 1942 and was completed only in 1947 due to the war events. The experiment reasonably confirmed the discrepancy between Dirac's theory and experimental data. Shortly after, Lamb and Retherford showed that the level $^2P_{1/2}$ is about 1058 MHz lower in energy than the level $^2S_{1/2}$ by directly observing the transition between the two levels, using a microwave beam of the appropriate wavelength. The theoretical description was then given by quantum electrodynamics. "Cocodrile"

Pavia - II

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- The failure of the project - due to harsh personal conflicts between the two leaders - caused the scattering of the group. Bassani, Tosi and Celli moved to the USA; Camagni to the Ispra Center, and Chiarotti (1962) to Messina. According to Chiarotti, the loss of this opportunity was compensated by the dissemination of Solid State Physics in the country. $\rightarrow$ Chiarotti's interview by Ilaria Bonizzoni and Giuseppe Giuliani (May 11, 2000).

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- The topics studied in Pavia were color centers in alkali- halides and, starting from 1960, semiconductors. The research on color centers has proved less far-sighted than that on semiconductors. Indeed, Frederick Seitz's emphasis on this area of research (1946), although cleverly calibrated, was overstated. "BCFG"

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- Andrea Frova (1937) systematically applied this new technique that became a standard procedure in studying surface electronic states, along with the modulation of the light wavelength [$\rightarrow$ modulation spectroscopy].
- In 1960, color centers research focused on Chiarotti's idea of studying the X-ray production of color centers in *KCl* at low temperatures, including liquid helium. There were two challenging issues: mastering the cryogenic techniques starting from scratch and the need to operate in the UV region below 2000 $\mathring{A}$, i.e., in a vacuum.

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- These difficulties were overcome in about five years (!). After that, the research continued until the mid-seventies, with results of some interest.
- On the theoretical side, Bassani and Celli significantly contributed to the band theory in semiconductors. A significant number of papers by Bassani, as those on the pseudo-potential developed with Celli and the collaboration with many foreign researchers, brought his name to the international community's attention. Indeed, Bassani's work trained the first new generation of Italian theoretical physicists in the solid state.

Between Milano and Parma

Scientific relations: Utrecht and Leida - Theoretical Physics (Sybren de Groot).

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- In 1964, Fieschi went to Parma with some of his coworkers. Fieschi, together with Andrea Levialdi (1911-1969), proposed the foundation of a CNR laboratory on the structure of matter. Its main characteristic - advocated by Levialdi - would have been the interweaving of cultural and professional skills of chemists and physicists. The laboratory will be built and, according to Fieschi, its ideal director would have been Levialdi who, unfortunately, succumbed to an incurable disease during a work trip to Cuba (1969).

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- In 1957, Boato attended the Varenna School on Solid State Physics organized by Fausto Fumi. "In Varenna, I came into contact for the first time with the wide range of problems of crystalline bodies, and I was lucky enough to meet some European and US top solid-state physicists."

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- Back to Genova, Boato decided to open new research lines with his direct collaborators, including Giacinto Scoles and Carlo Rizzuto: transport properties of rare gases in solid state and superconductivity.

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Foreign scientific relations: Alfred Kastler, Charles Hard Townes and Nicolaas Bloembergen

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- In1960, Gozzini organized a Summer school on radio frequency spectroscopy in Varenna: "The Proceedings of the School are collected in a volume which has proved to be an extensively used textbook in the sixties, and even today it is still extremely useful (Gozzini, 1987)"

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Foreign scientific relations: Institute for Nuclear Studies di Chicago, Chicago; Leida (cryogenic techniques).

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- Giorgio Careri (1922-2008) graduated in Industrial Engineering and Chemistry in Rome in December 1944, immediately after the city's liberation. After graduating, he refused a job offer and graduated in Physics (1946).
- Edoardo Amaldi asked Careri to build a mass spectrometer. "I had to build something I did not even know the name of." The construction of the spectrometer faced the typical difficulties of the years of reconstruction. The U.S. still considered the mass spectrometer a strategic material (until 1950): therefore, it was not possible to buy any components. Emilio Segre, violating a ban brought from the U.S. a couple of resistors of $10^{12}\Omega$, necessary for the input circuit of the ions detector. No voltage stabilizers were available. "We had to obtain the needed 200 V with batteries of accumulators abandoned by the U.S Army. Every night, some died, and early in the morning, we had to go hunting for those who had died during the night and replace them".
- Mass Spectrometer.
- Careri and the vacuum pumping system.

Roma II

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- The mass spectrometer was used to study chemical kinetics and geochemistry problems. The cryogenic techniques to study the diffusion coefficients in diluted mixtures of $H_2 - D_2$ and ${}^3He - {}^4He$; ions motion in liquid helium; electrically charged vortices in liquid helium.

Istituto di Elettroacustica - Roma

- The Institute of Electroacoustics of CNR was established in Rome in 1936 in the building of the Institute of Physics located in via Panisperna. Promoter and first president of the Institute was Orso Mario Corbino. Since the beginning, the research developed in the fields of musical and environmental acoustics, transducers and ultrasound physics.

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- In 1955, as part of the Ugo Bordoni Foundation, Daniele Sette (1918-2013) promoted a research group which - first in Italy - dealt with semiconductors physics.

Palermo I

International connections: MIT (John van Vleck).

- The development of the physics of matter in Palermo is linked to the names of Ugo Palma (1027-2012) and Beatrice Vittorelli Palma (1930-2008). Ugo Palma graduated in Physics in Palermo in 1947; Beatrice Vittorelli four years later. Director of the Institute of Physics was then Enrico Medi (1911 - 1974); his leadership is remembered by the Palma's as follows: "These [six years since the end of the war] were empty years for the Institute of Physics, a delay difficult to overcome; those years were perhaps crucial in forming the decision of Donato Palumbo and Gaetano Riccobono to leave Palermo "Palma's".

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- The arrival in Palermo of Mariano Santangelo as director of the Institute marked a turning point: "He brought an atmosphere, before unknown, of encouraging friendship, discussions and hard work. He promoted any activity or project with possibilities of development. His presence opened a decade of great stability, the basis for all further developments".

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- The research topics developed in Palermo included: interactions between electronic and vibrational transitions in magnetic crystals; collective motions of protons in non-ferroelectric crystals; ion and electronic cascades in light-sensitive crystals; electronic paramagnetic resonance of free radicals.

Physics of Matter in Ispra

- At the end of 1957, the CNRN (National Committee for Nuclear Research, established in 1952), in agreement with Fumi and Giulotto favored the creation of a small group in Pavia with the prospect of transferring it to the new nuclear Center of Ispra. Paolo Camagni (1931 - 2000) coordinated the group and moved to Ispra in 1959.

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- Camagni was joined by Adriano Manara and by Alfonso Merlini (1926-2014) who was entrusted with the group's direction. Camagni continued researching the production and the properties of defects in crystalline solids. Merlini's group studied the properties of solids with X-ray techniques.

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- The transformation of the Center into a community structure has progressively reduced the role of the Solid State Physics Laboratory.

Solid State and neutron diffraction

- Given the construction of the Ispra Center, the CNRN, on a proposal from Amaldi, decided to set up a research group to study the properties of solids with neutron diffraction. Initially (1957), Giuseppe Caglioti (1931), recalled by Argonne, Antonio Paoletti (1930 - 2019) and Francesco Paolo Ricci (1930 - 2000) were involved in the project.

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- When they returned to Italy, the projects had changed: The CNRN became CNEN, and the Ispra Center became a center of the European Community. The CNEN decided to set up its own research Center in Rome (at Casaccia): Caglioti and Ricci went to Ispra, while Paoletti went to Casaccia, where he developed the first European polarized neutrons spectrometer, which was used to study the magnetization density in metals and ferromagnetic alloys. The two groups became operational in 1960; however, The 'Ippolito case", which upset the CNEN in 1963, negatively impacted these groups' activity.

Becoming an organized community

- After the war, the reference points in Italy were the nuclear and cosmic rays physics, cultural heritage of Enrico Fermi and Bruno Rossi. The physicists, who for local contingencies or personal choices were oriented towards what will later be called the Physics of Matter, devoid of strong cultural or organizational references in the pre-war period were forced to look abroad.

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- In Italy, the connections between researchers were mainly indirect, through the congresses of the Italian Physical Society (SIF) and, later, through the schools of Varenna. In particular the School of 1956 organized by Giulotto, that of the following year organized by Fumi and that of 1960, organized by Gozzini.

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- The process of institutionalization of the research started in the first sixties and ended, provisionally, in 1994 with the foundation of the INFM (National Institute for the Physics of Matter), financed directly by the government as it happened in 1971 for the INFN (National Institute of Nuclear Physics).

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- In 2003, the government of Mr. Berlusconi, without any wariness about the fate of a young research structure and its impact on a strategic research field, inserted the INFM into the restructured CNR, leaving outside the other two National Institutes (INFN, INAF).

Epilogue

- The post-war period saw scientists engaged in a process of reconstruction made dramatic by the war devastation, the overall backwardness of the country, and of its scientific facilities. The progressive increase in the number of physicists, the raising of their professional profile, the increasing research funding allowed the Italian community of physicists to enter entirely - in about two decades - within the a wider international community.

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- A country in which the education system is not considered the foundation of the future, a country from which young graduates migrate without their output flow being balanced, both quantitatively and qualitatively; a country where the average technological level of the industry is lagging, and the materials and equipment of the research laboratories come, to a considerable extent, from abroad; such a country and its scientific research is set to play an increasingly marginal role in the international context.

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- This was certainly not the hope of the scientists who - after the material and moral devastation of the war - had taken up again with enthusiasm to "question Nature".

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