

WOLTE 11
Tutorials on Low temperature Electronics
Minatec/INPG, Grenoble, 7 July 2014

Chair: F. Balestra and G. Ghibaudo

8h50: Lecture 1 “Survey of Low-Temperature Electronics”

By Randall Kirschman (Consultant, CA, USA)

This tutorial will review the following topics from room temperature down to a few kelvins:

- (a) general semiconductor device behavior (diodes, BJTs, HBTs, FETs)
- (b) low-frequency noise in transistors
- (c) characteristics of passive components (resistors, capacitors, inductors)
- (d) application examples of low-temperature electronics.

This tutorial will be of interest to persons who want a background in the low-temperature behavior of semiconductor devices and other electronics components and materials.

Randall Kirschman

Dr. Randall Kirschman is an internationally recognized authority on extreme-temperature electronics. He has been consulting to industry, government and academe since 1980 in the areas of microelectronic materials and fabrication technology, and electronics for extreme temperatures. Before going into business for himself, he managed an R&D processing laboratory at a division of Eaton Corporation. Prior to that he was on the staff of the Jet Propulsion Laboratory, performing research on a variety of semiconductor materials and devices. He edited the 1986 IEEE Press book Low-Temperature Electronics. He completed his undergraduate studies at the University of California, and earned his Ph.D. in Physics and Electrical Engineering at the California Institute of Technology.

10h30: Coffee break

11h00: Lecture 2 “Electronics for cryogenic detectors for high energy particle physics”

By Gianluigi Pessina (INFN, Milan, Italy)

Abstract

The more and more challenging features required for the read-out electronics in particle physics applications have continuously called for high technology devices. Researches which use bolometric, scintillating or semiconductor high impedance detectors, such as those experiments devoted to the dark matter or to the double beta decay, demand ultra low noise amplifiers. Moreover, the signal to noise ratio increases by minimizing both the thermal contribution and the input stray capacitance which leads to place the front-end electronics at cryogenic temperatures, as near as possible to the detector. Other sensors, such as the TES detectors coupled with RF-SQUID, allow multiple channels multiplexing in order to reduce the number of wires and share expensive resources. Such techniques need high bandwidth amplifiers operating at deep cryogenic condition up to radiofrequencies. Therefore, the most important low temperature electronics requirements in various particle physics applications have been overviewed. The main technological steps have also been summarized in this paper.

This speech is focused on the circuit design of low noise, low background, high stability cryogenic systems for particle detectors

Gianluigi PESSINA

Gianluigi Pessina is working in the design of front-end electronics since 1986. He was and is involved in several projects in the fields of high energy and neutrino physics. Part of his research is spent with cryogenic electronics for the readout of low temperature detectors. At present he is taking care of the electronics systems of CUORE and LUCIFER to be run in the Underground Laboratory of Gran Sasso and the very front-end monolithic chip of the RICH upgrade at LHCb, CERN. He is coauthor of more than 400 publications: More about Gianluigi Pessina can be found at <http://pessina.mib.infn.it>.

12h30: Lunch

13h50: Lecture 3 “A wide introduction to quantum IR imaging”

By Olivier Gravrand (CEA-LETI, Grenoble, France)

IR imaging relies on the detection of small energy photons which implies different issues compared to visible light imaging. Two main detector families are available nowadays. First, this photon energy may be converted in heat and detected by a bolometer, or this photon can be absorbed in an adapted narrow gap semiconductor and give birth to an electron-hole pair. This second category, usually called “quantum IR detector” and allows very high performance and higher complexity IR imagery.

This tutorial aims at introducing the quantum IR imaging issues both from a performance and technological point of view. Starting from basic physical phenomenon exploited in quantum detectors the first part will be devoted to a large overview of detection structures usually used for quantum detection (from PC to PV). The few competing material systems in the IR field will be reviewed, from 3-5 bulk materials (InGaAs, InAsSb, InSb) to 2-6 (HgCdTe) with perspectives to newcomers “synthetic” narrow gap materials such as QWIPs and superlattices.

The second part will be devoted to a special focus on the photodiode, which remains the main photo-detection structure today. Its intimate functioning will be exposed. Dark current and photocurrent mechanisms will be reviewed and linked to photodiode performances, with an emphasis to a major figure of merit for the photodiode: the minority carrier lifetime. The specific case of avalanche photodiodes will be exposed. A particular attention will be drawn to performance evolution with operating temperature in perspective of the SWAP (size weight and power) trends.

The last part will review the past evolution of IR detection structures (1st and 2nd generation) and will open to the expected future generation of IR focal plane arrays. Will it be dual-band focal plane arrays? Or simply very large retinas with ultrafine pixel pitches operating at very high temperature? What role avalanche photodiodes may play in this context in the near future? What kind of additional optical functions might be added onto the detector chip itself?

This lecture is intended for student, scientists and researchers interested in high performance IR imagery. The idea is to give a better understanding of the functioning of IR FPAs in order to help the user to optimize the use and/or the optical design around the IR retina.

Olivier Gravrand

After a PhD in physics applied to earth science (high performance magnetometer design) at the IPGP (Institut de physique du globe de Paris), he joined the LETI IR group in 2001, in charge of IR detector electro-optical characterization. Since then he has been working on HgCdTe, InSb, InGaAs and 3-5 super-lattice photodiodes, both from the characterization, design and simulation point of view, in close collaboration with the Sofradir Group.

15h30: Coffee break

16h00: Lecture 4 “Developments of cryogenic millimeter wave front-ends for Radio Telescopes”

By Anne-Laure Fontana (IRAM, Grenoble, France)

IRAM (Institut de RadioAstronomie Millimétrique) is an international research institute for radio astronomy that maintains and develops two observatories: the 30-meter telescope located on Pico Veleta near Granada in Spain, and the Plateau de Bure Interferometer in the French Alps, both operating at millimeter wavelengths (frequency range ~80-370 GHz). IRAM is specialized in the development of cryogenic low noise high frequency receivers and electronic components for its own needs as well as for other radio astronomy centers.

In this tutorial, the existing IRAM observatories and their upgrade status will be presented.

In particular, the presentation will focus on ongoing developments of cryogenic electronics instrumentation for radio astronomy carried out in the IRAM laboratories.

Anne Laure FONTANA

Anne-Laure Fontana received the S.M. degree in microelectronics and microwaves from the Sciences and Technologies University of Lille, France, in 2002. Since 2003, she has been with the IRAM, Saint Martin d’Hères, France, where she is involved in the development of cryogenic low noise millimeter-wave receivers. Her research interests include millimeter-wave receivers and in particular the receiver optics and the multi-pixel arrays