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THE DEVELOPMENT OF A SUPERCONDUCTING GAMMA CAMERA

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Abstract.- We described the development of first gamma camera, the detector of which is a suspension of superheated superconducting granules. This device has been designed in view of clinical utilization. It allows the obtention of 81 x 81 mm pictures with a spatial resolution of 1.27 mm.

In spite of the successful introduction of scanners for medical exploration, the need of gamma-cameras remains. In a scanner, the "view" of the internal of the body is provided by differences of absorption of X rays emitted by a tube diametrically opposed to a detector (scintillator NaI or semiconductor). The rotation of the tube and its associated detector provides "slices" of the body. The quality image is good but one get only anatomical informations. The spatial resolution is about 10 mm.

On the contrary a gamma-camera is a very large detector (usually NaI up to 40 cm in diameter). A radionuclide is injected to the patient and the diffusion of the gamma emitter can be followed dynamically. The optics is provided by lead collimators, the quality image is bad : 3 mm of spatial resolution in the optimum conditions blurred by Compton diffusion but one can deduce flow measurements, dynamic behavior, etc... The need for better resolution is urgently felt but the progress of NaI cameras are now very slow. Furthermore the introduction of medical cyclotron providing short-live radio nuclides of high intensity requires highcounting rates, which are obtained only by a degradation of the image quality : in NaI cameras the gamma is detected by a set of 19, 37 or 64 photomultiplier (PM) looking at the fluorescence spot. Each PM has to be tuned on the photoelectric peak and their intensities are normalised to the total of all the output currents before a localisation can be made.

In front of this situation we felt that the feasibility of a gamma camera based on a superheated superconducting detector should be tested.

It is well known that superheated superconducting metastable states can be easily observed in small spherical granules of type I superconductor (Hg, In, Sn under 50 μ). The metastability is broken under irradiation by an X or a γ ray if the energy loss of the photon inside the granule is higher than the energy barrier between the metastable and the normal state. This difference depends on the difference between the superheated critical magnetic field \( H_{sh} \) and the external field applied to the granule. In other words, a collection of superheated superconducting granules is a detector with the unique property to locate, by principle, the materialization of the photon within a discrete granule, furthermore its average energy barrier can be monitored by an external magnetic field. To detect the transition of the granules from superheated to normal state we used the disparition of the Meissner effect. At LT 14, two of us (C.V. and G.W.) reported the very first detection in real time of the transition of one granule under irradiation (in that case by transition radiation photon created by a 6 GeV electron interacting with the granule) /1,2/. In a coil, 140 μ in diameter surrounding a 20 μ mercury grain a tiny current is generated during the penetration of the external magnetic field in the grain. This tiny current is detected by a low impedance charge preamplifier /3/. Since that time we have improved this preamplifier and we can detect the same grain in a 1 cm loop. This progress allows us to realize a large area detector. The detector we built has a matrix organisation by analogy with wire chambers. A slice of granules is sandwiched between two arrays of U shaped
inductive loops. In each array the loops are parallel to the same direction but the two arrays are perpendicular one to the other. Thus, the flipping of granule is detected on one loop of each array. The two signals are sent to a coincidence discriminator and the address on the event given by the identification of the two loops is sent to a computer (Figure 1).

1.5 K helium vessel. This vessel is fed in parallel by a capillary pipe and, for initial filling, a larger pipe including a cold valve to a 6 liter helium vessel at atmospheric pressure. A common vacuum chamber allows direct access to the detector and its 256 wires thermalized when the outside jacket is removed. The attenuation introduced by the cryostat is completely negligible in the practical medical range of $\gamma$ rays (60 to 140 keV). This cryostat has ten hours of autonomy. It can be kept in operation during transportation to the bed of the eventual patient because it has an internal cryopump. It can be slightly tilted ($\pm 30^\circ$).

The preamplifiers output are interfaced with a minicomputer fulfilling two tasks:

1) the management of the data flow together with the magnetic field monitoring.
2) all the software imaging techniques: zooming, 3D projection, isocontour, homogeneity corrections, etc... available on the most advanced $\gamma$ cameras.

The pictures we would like to show at the conference are obtained with a detector of tin granules irradiated by $^{131}_\text{Cs}$ radionuclide.

Further studies will be continued specially regarding the energy selection but we can already stress that such a gamma camera offers a much better spatial resolution independent of any tuning and a higher counting rate.

**Fig. The 81 x 81 mm matrix detector.**

Since we have in mind clinical utilisation we limited our spatial resolution to 1.27 mm which is the period of each array. However with no more problems we can have a 150\(\mu\) resolution. The size of the matrix is 81 x 81 mm and has been restricted only by economical consideration (in small scale production the price of one present amplifier is about 300 F). We estimate that for brain and cardiac studies 20 cm in diameter is enough for such a detector. Four preamplifiers can be housed in a 1.5 x 10 x 20 cm volume. An hybrid version cheaper and four times smaller of a similar preamplifier is already under development. Thus the 128 preamplifiers are housed in a 6" x 19" rack.

A dedicated cryostat was built. The detector is cooled by a cold plate linked to a small 1.5 K helium vessel. This vessel is fed in parallel by a capillary pipe and, for initial filling, a larger pipe including a cold valve to a 6 liter helium vessel at atmospheric pressure. A common vacuum chamber allows direct access to the detector and its 256 wires thermalized when the outside jacket is removed. The attenuation introduced by the cryostat is completely negligible in the practical medical range of $\gamma$ rays (60 to 140 keV). This cryostat has ten hours of autonomy. It can be kept in operation during transportation to the bed of the eventual patient because it has an internal cryopump. It can be slightly tilted ($\pm 30^\circ$).

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**References**