

Codice	Esperimento	Gruppo
	LIGHT	5
Rapp. Naz.: Daniel Camin		

Rappresentante nazionale: Daniel Camin

Struttura di appartenenza: MI

Posizione nell'I.N.F.N.:

PROGRAMMA DI RICERCA	
A) INFORMAZIONI GENERALI	
Linea di ricerca	<ul style="list-style-type: none"> - Trasmissione di segnali analogici via mezzi ottici. - Elettronica a basso rumore.
Laboratorio ove si raccolgono i dati	Milano
Sigla dello esperimento assegnata dal laboratorio	LIGHT
Acceleratore usato	
Fascio (sigla e caratteristiche)	
Processo fisico studiato	<ul style="list-style-type: none"> - Anelli di retroazione con ingresso passivo e disaccoppiamento Galvanico. - Processo di generazione-ricombinazione in dispositivi ad effetto di campo.
Apparato strumentale utilizzato	Generatori di impulsi ottici- Convertitori elettro-ottici- Oscilloscopi ad ampia banda. Criostati e camere termiche. Analizzatori di spettro FFT. Ambiente di modellazione di dispositivi a semiconduttore IC-CAP. Elettrometri e nanovolmetri ad alta risoluzione.
Sezioni partecipanti all'esperimento	Milano
Istituzioni esterne all'Ente partecipante	
Durata esperimento	3 anni
B) SCALA DEI TEMPI : piano di svolgimento	
PERIODO	ATTIVITA' PREVISTA
2004	<ul style="list-style-type: none"> - Analog link con ingresso passivo via fibra ottica basato sull'OCCM. - Sviluppo software di controllo v.2 per il nostro criostato, a doppio loop di retroazione.
2005	<ul style="list-style-type: none"> - Integrazione dell'€TMOCCM come singolo dispositivo. - Analisi di strutture sub-micrometriche ST, di interesse INFN, mediante spettroscopia di rumore a temperatura variabile.
2006	<ul style="list-style-type: none"> - Sviluppo di ulteriori applicazioni dell'OCCM con ricaduta in ambito medicale e industriale. - Spettroscopia di rumore su dispositivi MOS ST, a altri dispositivi di particolare interesse per la Fisica sperimentale.

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno 2004

Codice	Esperimento	Gruppo
	LIGHT	5
Resp. loc.: Daniel Camin		

Struttura
MI

PREVENTIVO LOCALE DI SPESA PER L'ANNO 2004
In KEuro

VOCI DI SPESA	DESCRIZIONE DELLA SPESA					IMPORTI				A cura della Comm.ne Scientifica Nazionale	
						Parziali		Totale Compet.			
						SJ		SJ			
Viaggi e missioni	Interno	Meetings a ST Catania (2 p x 1kE)					2.0		5.0	0.0	
		Lavori di microsaldature per criostato presso LNL					1.0				
		Meetings e conferenze					2.0				
Estero	Partecipazione al Workshop on Low Temperature Electronics (WOLTE) 6, presso ESA/ESTEC (2p x 1.5 kE)					3.0		8.0	0.0		
	Partecipazione al Nuclear Science Symposium (2 p x 2.5 kE)					5.0					
Materiale Consumo	Materiale di optoelettronica: LEDs, LASERs, Fibre e Optocouplers					5.0		12.5	0.0		
	Contratto di manutenzione software IC-CAP					2.0					
	Microcoax (Cavi coassiali) in acciaio Lake Shore					1.5					
	Componentistica Elettronica e Informatica varia					2.0					
	Elio liquido					1.0					
	Metabolismo					1.0					
Trasp. e facch.								0.0	0.0		
Spese Calcolo	Consorzio	Ore CPU	Spazio Disco	Cassette	Altro			0.0	0.0		
Affitti e manutenz. apparecchiati.								0.0	0.0		
Materiale inventariabile	Generatore d'impulso ottico					25.0		25.0	0.0		
Costruzione Apparati								0.0	0.0		
Totale								50.5	0.0		

 Sono previsti interventi e/o impiantistica che ricadono sotto la disciplina della legge Merloni ?

Breve descrizione dell'intervento:

Mod EC./EN. 2

(a cura del responsabile locale)

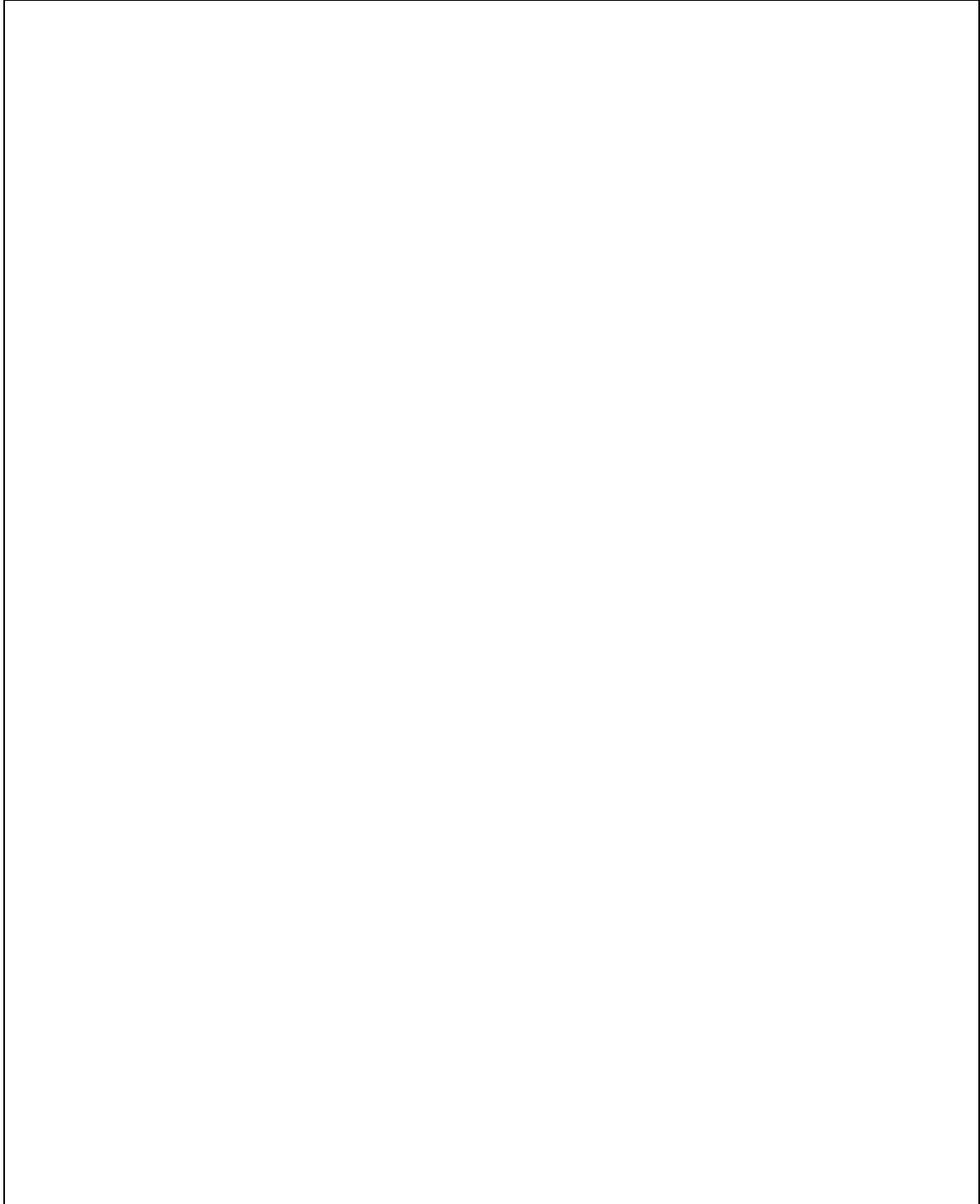
ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno *2004*

Struttura
<i>MI</i>

Codice	Esperimento	Gruppo
	LIGHT	5
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ALLEGATO MODELLO EC2



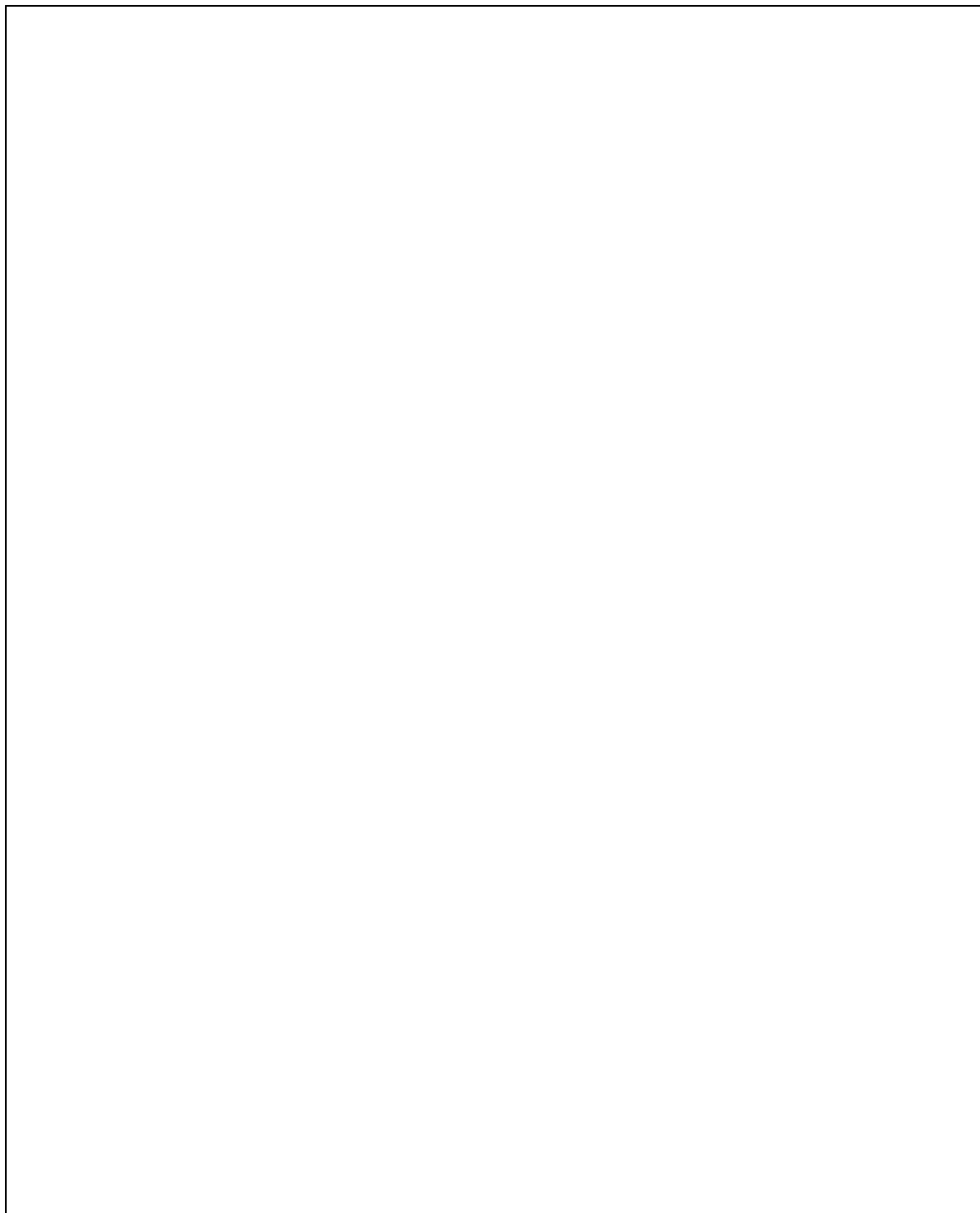
ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno *2004*

Struttura
<i>MI</i>

Codice	Esperimento	Gruppo
	LIGHT	5
Resp. loc.: Daniel Camin		

ALLEGATO MODELLO EC2



Codice	Esperimento	Gruppo
	LIGHT	5
Rapp. naz.: Daniel Camin		

PREVENTIVO GLOBALE DI SPESA PER L'ANNO 2004

In KEuro

Struttura	A CARICO DELL' I.N.F.N.										A carico di altri Enti
	Miss. interno di cui SJ	Miss. estero. di cui SJ	Materiale di cons. di cui SJ	Trasp. e Facch. di cui SJ	Spese Calc. di cui SJ	Affitti e Manut. Appar. di cui SJ	Mater. inventar. di cui SJ	Costr. appar. di cui SJ	TOTALE Compet. di cui SJ		
MI	5,0	8,0	12,5				25,0			50,5	
TOTALI	5,0	8,0	12,5				25,0			50,5	

NB. La colonna A carico di altri enti deve essere compilata obbligatoriamente

Note:

Nuovo esperimento	Gruppo
LIGHT	5

PROPOSTA DI NUOVO ESPERIMENTO

Ci sono due linee di ricerca previste in questa proposta. La prima prevede lo sviluppo di nuove applicazioni di un concetto circuitale altamente innovativo basato sulla optoelettronica lineare denominato "Optically Coupled Current Mirror" (OCCM). La seconda linea comprende lo sviluppo ulteriore della tecnica nota come Spettroscopia di Rumore di Bassa Frequenza a Temperatura Variabile (LFN vs T), applicata alla identificazione dei contaminanti presenti nei transistori ad effetto di campo, che danno origine al rumore del dispositivo stesso.

In seguito verranno dettagliate entrambe le linee di ricerca, strettamente legate alle problematiche dell'amplificazione e del trasporto del segnale tipicamente incontrate negli esperimenti di Fisica delle particelle e delle astroparticelle.

1) Studio e sviluppo di nuove applicazioni dell'OCCM:

Il concetto OCCM e' stato formulato come soluzione ad un annoso problema mai risolto in passato, cioe' la misura diretta della componente continua della corrente di anodo di tubi fotomoltiplicatori polarizzati con catodo a massa. Piu' precisamente si trattava di misurare con elevata risoluzione la luce di fondo-cielo dei due telescopi prototipali del Rivelatore di Fluorescenza Atmosferica dell'esperimento Auger. In particolare la determinazione del passaggio di stelle di riferimento sulla superficie focale dei telescopi, consistente in un array di 20 x 22 fototubi, ha permesso di verificare il loro puntamento assoluto con grande precisione [1-3]

Va pur detto che la misura di segnali generati dai rivelatori o, piu' in generale, che scorrono su dei conduttori isolati o comunque sottoposti ad alta tensione, fu risolta in passato mediante la implementazione di anelli di reazione ottici impieganti dei dispositivi optoelettronici noti come "Linear Optocoupler"(LO). Questi sistemi consistono in una parte trasmittente che si trova al potenziale del conduttore dove scorre la corrente di segnale da misurare, e una parte ricevente a potenziale di massa. Il feedback viene implementato da mezzi ottici (fibre oppure optocoppiatori). L'inconveniente piu' importante delle soluzioni impieganti il LO finora proposte risiede nella necessita' di dover portare al potenziale del conduttore dove viene generato il segnale, degli alimentatori richiesti dalla presenza dei dispositivi attivi (transistori, op-amps e simili) che si trovano nella parte trasmittente. Questo tipo di soluzione era chiaramente improponibile per il caso dell'esperimento Auger dove il numero di PMT's dei due telescopi prototipali raggiungeva circa il migliaio di pezzi. La caratteristica saliente del concetto OCCM risiede nel fatto che la parte trasmittente e' totalmente passiva trattandosi infatti di un LED e un fotodiodo collegati back-to-back ed interposti nel conduttore dove scorre il segnale da misurare. Diventa pertanto non piu' necessario dover portare alcuna tensione di alimentazione al potenziale del conduttore dove scorre la corrente da misurare. Questo semplifica notevolmente il problema e apre la strada ad altre applicazioni sinora ritenute impossibili da implementare mediante le tecniche correntemente utilizzate, ritenute lo "state of the art".

Il OCCM e' stato impiegato per la prima volta nell'implementazione di un "Misuratore di corrente continua con ingresso passivo ed isolamento Galvanico particolarmente per alta tensione" utilizzato per la determinazione della corrente di fondo-cielo dei due telescopi prototipali di Auger. Per tale Misuratore sono stati concessi all'INFN un brevetto negli Stati Uniti, e un altro nell'Unione Europea. Attualmente la domanda di brevetto nel Giappone rimane in stand-by come permesso dalla legge di tale Paese [4-6]

Il piano di lavoro di LIGHT comprende da un lato l'integrazione del Misuratore di Corrente in un singolo package per applicazioni in DC come e' il caso dei fototubi.

Questa attivita' sarebbe da svolgersi in stretto contatto con una ditta esterna in grado di fornire il necessario supporto tecnologico. Si prevede inoltre la implementazione di un link a fibra ottica con ingresso passivo

seguendo lo schema OCCM, in grado di trasmettere dei segnali analogici via fibra ottica. Questa tematica e' stata affrontata al CERN nell'ambito dello sviluppo della calorimetria a LAr a LHC. A tale scopo sono stati impiegati delle tecniche tradizionali di tipo "open-loop" ma non si e' riusciti a trovare una soluzione soddisfacente.

In seguito agli studi preliminari realizzati sui links analogici basati sul concetto OCCM, che comprende la implementazione di un sistema tipo "closed-loop" si ritiene di grande interesse esplorare questa via che aprirebbe delle possibilita' applicative non solo nella Fisica sperimentale ma che potrebbe avere una ricaduta anche in ambito industriale e medicale.

L'ottimizzazione del link ottico richiede della strumentazione adatta allo scopo, in particolare un generatore di impulsi ottici a lunghezza d'onda di 850 e 1300 nm. Il comportamento alle basse temperature deve inoltre essere investigato. A tale scopo verra' invece utilizzata della strumentazione gia' acquisita nell'ambito degli esperimenti NOISE ed MICRO(GV).

2) Spettroscopia di rumore di bassa frequenza applicata ai transistori ad effetto di campo.

Nell'ambito dell' esperimento NOISE che termina nel 2003, abbiamo messo a punto un set-up sperimentale in grado di determinare la energia di attivazione dei contaminanti che danno origine al rumore Lorentziano in strutture FET. Tale tecnica prevede la misura della densita' spettrale di rumore di dispositivi FET raffreddati a temperature criogeniche, combinata con il fitting degli spettri ottenuti. A tal modo e' possibile determinare univocamente l'elemento chimico generante il rumore di generazione-ricombinazione. Il nostro lavoro ha contribuito a migliorare la sensibilita' di questa tecnica sviluppata nella seconda meta' degli anni 80[7], applicandola alla investigazione di dispositivi JFET al Ge destinati all'ambiente criogenico. Questi dispositivi sono stati sviluppati in collaborazione con ricercatori USA con finanziamenti NASA. Recentemente questa tecnica e' stata utilizzata con successo nella determinazione di contaminanti in MOSFET al Si di dimensioni submicrometriche prodotti da ST Microelectronics. Diversi gruppi RDdi ST Microelectronics hanno apprezzato la potenzialita' offerta dalla tecnica LFN vs T, complementare a diversi metodi di indagine da loro gia' implementati su wafers o strutture di grande area. In tempi recenti e' stato firmato un protocollo di non disclosure agreement che ci permettera' di analizzare dispositivi provenienti direttamente dalla linea di produzione. La interazione con questa foundry ci mettera' in grado di meglio comprendere le tecnologie implementate nella realizzazione di dispositivi a basso rumore, di potenziale interesse per lo sviluppo di strutture monolitiche e rad-hard di impiego nella fisica sperimentale. Si intende inoltre estendere l'idagine spettroscopica ad altri dispositivi emergenti d'interesse per le applicazioni a basso rumore.

[1]S.Argiro, D.V.Camin, M.Destro, C.K.Guerard, Nucl.Instr.and Meth.A 435 (1999)484-489

[2]S. Argiro', D.V.Camin, V.Grassi,et al "The analog signal processor of the Auger fluorescence detector prototype", Nucl. Instr. and Meth. A 461/1-3 (2001) pp. 440-448.

[3]D.V.Camin, V. Grassi, F. sanchez and V. Scherini, "Tracking stars with the Auger fluorescence detector of teh Pierre Auger Observatory". Presented to the 2003 Pisa Meeting, to be published by Nucl. Instr. and Meth.

[4-6]D.V.Camin, "Direct Current Meter with Passive Input and Galvanic Isolation , Particularly for High Voltage":

- US Patent Number 6,316,930 (2001).

- UE Patent Number EP 1 014 098 B1(2003)

- Application to the Japan Patent Office Number 11-359282 (17 Dec 1999)

[7] V.Grassi, C.F. Colombo, D.V. Camin, Low Frequency Noise versus

Temperature Spectroscopy of recently designed Ge JFETs, IEEE

Transactions on Electron Devices vol. 48 n.12 pag.2899 (2001)

Tracking Stars with the Fluorescence Detector of the Pierre Auger Observatory.

Daniel V. Camin,^a Valerio Grassi^a, Federico Sánchez^a, and Viviana Scherini^a

^aDipartimento di Fisica dell'Università di Milano and INFN Milano, Via Celoria 16 (20133), Italy

Recording tracks of stars traversing the field of view of the Auger's fluorescence detector (FD) is a powerful tool to monitor various FD parameters. Regular control of those tracks would allow checking the telescopes stability during the whole life of the experiment, estimated to be about 20 years. The prototypes used during the engineering array phase (EA) have been equipped with a novel optoelectronic system that measured the DC anode current. Dim stars were clearly recorded. We report results of a reconstruction performed to determine the pointing of a telescope as well as comparisons of a PMT's response to shower and star signals.

1. Introduction

The Auger fluorescence detector comprises 24 telescopes each one consisting on a large, $3.5 \text{ m} \times 3.5 \text{ m}$ mirror of 3.4 m focal distance and a 2.2 m diameter aperture. A camera of spherical surface consisting of an array of 20 columns by 22 rows of Photonis XP 3062 PMT's is positioned at about 1.7 m of the mirror's centre of curvature. For a point object like a star, the spot size is 0.5° in diameter, i.e. one third the pixel size.

The telescopes look to the sky and are subject to the background light. Absolute pointing of the telescope, its stability and the uniformity of the photocathode response (previously investigated [1]) can be determined by analyzing stars signals.

The PMTs are biased with positive supply, i.e. cathode grounded. This ensures simplicity of operation and better stability of response but, in principle, it seems that direct measurement of the DC or very slow component of the background light will be impossible to perform. We could solve for the first time this very old problem by implementing an optically coupled feedback loop of novel design [2,3] included in the 880 Head Electronics, that serve the PMTs of the two telescopes. With this implementation, stars of visual magnitude 5.4 or even dimmer were visible. Brighter stars like α Lyræ clearly showed a structure when the light spot was traversing the PMTs photocathode (Fig.1). We also analyzed back-

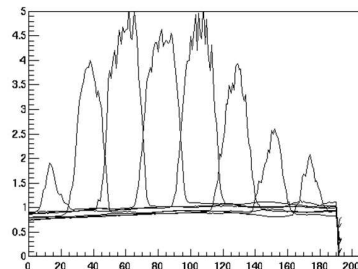


Figure 1. The first stars signals seen by the FD Optical Current Monitor on June 25, 2001. The time slot is 20 s. A star takes about 6 min to traverse a PMT along its diameter. The fluctuations at the top do not seem compatible with Poisson statistics. The vertical scale is mean anode current in μA .

ground data by evaluating the variance of the baseline fluctuations. In the following sections we will report on the use of star tracks to determine the pointing of one of the telescopes and on the measurement of photocathode anisotropy.

2. Analyzing Signals

During the analysis of the star signals, it was noted that despite the fluorescence signal and a star signal are in a completely different time scale, both left in the same PMT a very simi-

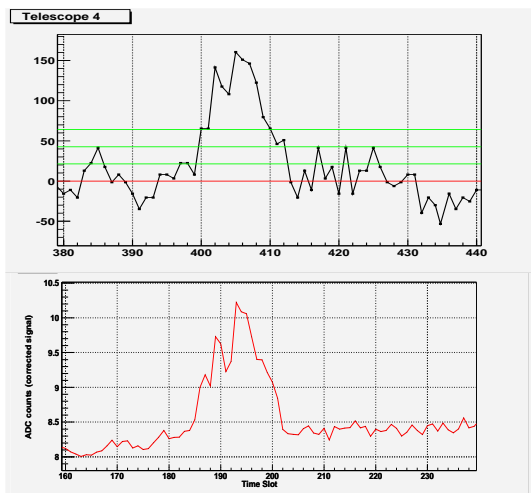


Figure 2. Signal from a fluorescence event (top, time slot 100 nsec) and from a star (bottom, time slot 30 sec). Although the time scale is quite different, we observe similar shapes.

lar pattern, Fig.2. This fact led us to think that the non-uniformity of the response observed were most probably to be assigned to photocathode anisotropy. To verify this, the mean shape of a star signals over 10 nights was evaluated. Results are shown in Fig.3 (top). The pattern seen at Fig.3 (bottom) corresponds to a slice cut of the photocathode's response obtained at our Lab using an xy table and an UV LED to simulate the transit of a star in a camera pixel.

The pointing direction of the camera's center for each telescope of the fluorescence detector can be tested minimizing $\chi^2 = \sum_{pixels} (\Delta\theta_{theor.} - \Delta\theta_{meas.})^2$ where $\Delta\theta_{theor.} = \delta_{star} - \delta_{pixel}$ (δ is the declination) and $\Delta\theta_{meas.}$ is calculated by $\Delta\theta_{meas.} = \sqrt{(0.75^\circ)^2 + (\frac{360^\circ}{24h} \frac{\Delta T}{2} \cos\delta_{star})^2}$ where ΔT is the pulse width.

We performed this analysis for 7 of the brighter stars and obtained the pointing of one telescope as $\theta = 125.71^\circ \pm 0.19$ and $\phi = 90.05 \pm 0.05$.

3. Conclusions

We have demonstrated a high-resolution star-tracking capability of the Auger FD. Dim stars were clearly identified with a novel optoelectronic

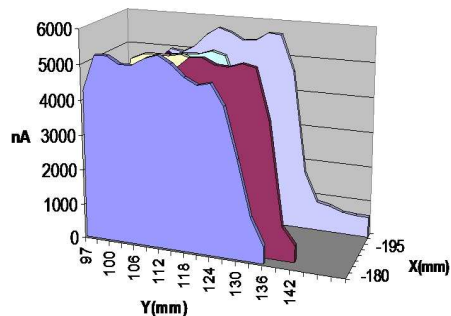
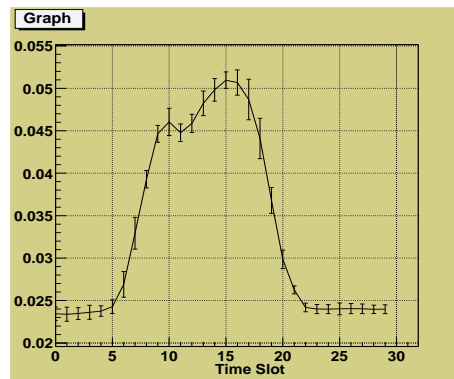


Figure 3. The average shape of star signals on the same PMT of 10 different nights (top) shows the photocathode anisotropy in one of the FD PMTs. The bottom panel shows the photocathode response obtained at the Lab making an xy scan.

system incorporated in the 880 PMTs of the two FD prototype telescopes. We have used stars data to verify the pointing of telescope $n^{\circ}4$ and to found the non-constant response (of aprox $\pm 10\%$) of the photocathode. This fact was later confirmed by xy scanning of a PMT illuminated by an UV LED.

REFERENCES

1. Bird et al., N.I.M. **A 349** (1994)592-599
2. Argiró et al., N.I.M. **A 435** (1999)484-489
3. Argiró et al., N.I.M. **A 461** (2001)440-448

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 1 014 098 B1

(12)

EUROPEAN PATENT SPECIFICATION

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23.04.2003 Bulletin 2003/17

(51) Int Cl.7: **G01R 15/22**

(21) Application number: **99204319.0**

(22) Date of filing: **15.12.1999**

(54) **Direct current meter with passive input and galvanic insulation, particularly for high voltage**

Gleichstrommessgerät mit passivem Eingang und mit galvanischer Isolierung, insbesondere für Hochspannung

Appareil de mesure de courant continu avec entrée passive et isolation galvanique, en particulier pour haute tension

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**

(74) Representative: **Mittler, Enrico**
c/o Mittler & C. s.r.l.,
Viale Lombardia, 20
20131 Milano (IT)

(30) Priority: **21.12.1998 IT MI982754**

(56) References cited:
US-A- 3 772 514 US-A- 4 070 572
US-A- 4 316 141

(43) Date of publication of application:
28.06.2000 Bulletin 2000/26

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• **PATENT ABSTRACTS OF JAPAN vol. 007, no.
051 (P-179), 26 February 1983 (1983-02-26) & JP
57 199961 A (MITSUBISHI DENKI KK), 8
December 1982 (1982-12-08)**

(72) Inventor: **Camin, Daniel Victor**
20141 Milano (IT)

EP 1 014 098 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Low Frequency Noise Versus Temperature Spectroscopy of Recently Designed Ge JFETs

Valerio Grassi, Carlo Francesco Colombo, and Daniel V. Camin

Abstract—During the investigation of cryogenic properties of recently developed Ge JFETs we have applied the technique known in literature as low frequency noise versus temperature spectroscopy (LFN versus T). Using this method we have determined the energy levels of traps associated to Lorentzian noise found in the 30 to 40 K temperature range. To perform this task we have developed a computer-controlled experimental setup able to set the temperature within ± 5 mK in the range 4 to 300 K during a spectral noise measurement. An approach for the calculation of the uncertainties that affect the evaluation of traps parameter is presented.

Index Terms—Ge JFETs, generation-recombination (GR) noise, low frequency noise versus temperature spectroscopy (LFN versus T), low temperature electronics.

I. INTRODUCTION

THE measurement of low frequency noise (LFN) is a powerful method for the determination of the nature of traps in field-effect transistors (FETs). Energy levels and eventually trap cross-sections could be derived from noise spectra taken at different temperatures. This approach, known in literature as low frequency noise versus temperature spectroscopy (LFN versus T) [1], [2], is not widely used although it shows important advantages compared to the deep level transient spectroscopy (DLTS) technique: LFN versus T in fact is able to evaluate how the impurities degrade the noise performances in a device when the device itself is biased and cooled in its operative conditions. That is the case of a JFET used in amplification of signals from infrared and visible sensors, or particle detectors, used on the ground or in space-borne instruments. Moreover, LFN versus T can be used at very low temperatures, where carrier freeze-out in silicon devices inhibits DLTS, allowing the investigation of shallow levels. LFN versus T technique, yielding the noise power spectrum for every operative temperature, is a useful tool for the development of low noise devices as it produces data for process characterization and modeling. LFN versus T spectroscopy capabilities are also independent on the device size. The same result was shown in [3] by applying the constant-resistance (CR-) DLTS technique.

On the contrary, LFN versus T spectroscopy cannot by itself distinguish if a trap is a donor or an acceptor or to determine the defect concentration, where this task is easily performed analyzing the polarity and the amplitude of a DLTS signal.

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Publisher Item Identifier S 0018-9383(01)10118-8.

We have performed LFN versus T spectroscopy during the investigation of low temperatures performances on a recently developed Ge JFET made by GPD Optoelectronics, Salem, New Hampshire, USA (formerly Germanium Power Devices). The device analyzed is a sample of a batch developed in the frame of a project aiming at the realization of FETs capable to operate at Liquid Helium (LHe) temperature with low noise and stable dc characteristics [4], [5].

II. THEORETICAL BACKGROUND

A typical low-frequency noise spectrum of a JFET shows one or more lorentzian components plus white noise. Lorentzian components are associated to generation-recombination (GR) centers in the channel or in the depletion region.

According to the previous work of Shockley and Read [6], the characteristic time constant of the trap giving origin to the GR process, depends on the temperature.

Sah [7], demonstrates that the noise due to GR process in the depletion region is the main noise source in a JFET and calculates the time constant associated to a GR center as:

$$\tau = \frac{1}{c_p(p_0 + p_1) + c_n(n_0 + n_1)} \quad (1)$$

where p_0 and n_0 are the steady state hole and electron concentration in the depletion region, and p_1 and n_1 are defined as: $p_1 = n_i \exp[E_i - E_t/kT]$ and $n_1 = n_i \exp[E_t - E_i/kT]$. In the expressions above, E_i is the intrinsic Fermi level, E_t the energy of the trap, n_i the intrinsic carrier concentration and c_p , c_n are the capture coefficients for holes and electrons, respectively. These last two terms are defined as the product of the capture cross section and the thermal velocity of the carriers: $c_p = \sigma_p v_{tp}$ and $c_n = \sigma_n v_{tn}$, where $v_{tn} = \sqrt{3kT/m_e}$ and $v_{tp} = \sqrt{3kT/m_h}$. The term m_e is the effective mass of the electron and m_h is the effective mass of the hole in the semiconductor analyzed. Since in the depletion region the hole and electron concentrations are negligible [8], (1) could be rewritten as:

$$\tau = \frac{1}{n_i \left\{ c_p \exp\left(\frac{E_i - E_t}{kT}\right) + c_n \exp\left(\frac{E_t - E_i}{kT}\right) \right\}} \quad (2)$$

The strong temperature dependence of τ is due to the temperature dependence of n_i , which decreases when the temperature decreases, as shown in (3) [9].

$$n_i = \sqrt{N_C N_V} \exp\left(-\frac{E_g}{2kT}\right) \quad (3)$$

where E_g is the gap energy and N_C , N_V the effective densities of conduction and valence band states.

In terms of spectral shape, when the noise of a JFET is measured at different temperatures, the corner frequency of a typical Lorentzian noise shifts to lower frequencies when the FET in analysis is cooled and to higher frequencies when the temperature is increased.

Scholz, Hwang, and Schroeder [10] and later Scholz and Roach [1], have developed a method based on noise spectra analysis to extract traps activation energies from an Arrhenius plot, as it is usual in DLTS technique. According to the theory developed in [10], the relationship between the trap energy, G-R time constant and the temperature may be extrapolated from the (2).

Assuming $E_t - E_i > 0$, by multiplying both side of (2) by T^2 , and making explicit n_i , c_n , N_C and N_V one can write:

$$\ln(T^2\tau) = \left(\frac{E_g}{2} - E_t + E_i \right) \frac{1}{kT} - \ln \left[\left(\frac{4k^2\sigma_n}{h^3} \left(6\pi^3 m_e^{1/2} m_h^{3/2} \right)^{1/2} \right) \right] \quad (4)$$

and for $E_t - E_i < 0$:

$$\ln(T^2\tau) = \left(\frac{E_g}{2} + E_t - E_i \right) \frac{1}{kT} - \ln \left[\left(\frac{4k^2\sigma_p}{h^3} \left(6\pi^3 m_e^{3/2} m_h^{1/2} \right)^{1/2} \right) \right]. \quad (5)$$

Since the intrinsic Fermi level E_i is expressed by the relation:

$$E_i = \frac{E_g}{2} + \frac{kT}{2} \ln \left(\frac{N_V}{N_C} \right) \quad (6)$$

and the second term of (6) is typically small compared to the trap energy, its contribution could be neglected [1].

Defining ΔE as the energy of the trap measured from the appropriate band (i.e., $\Delta E = E_C - E_t$ or $\Delta E = E_t - E_V$ for the (4) and (5), respectively) the following equations are obtained:

$$\ln(T^2\tau) \approx \left(\frac{\Delta E}{kT} \right) - \ln \left[\left(\frac{4k^2\sigma_n}{gh^3} \left(6\pi^3 m_e^{1/2} m_h^{3/2} \right)^{1/2} \right) \right] \quad (7)$$

$$\ln(T^2\tau) \approx \left(\frac{\Delta E}{kT} \right) - \ln \left[\left(\frac{4k^2\sigma_p}{gh^3} \left(6\pi^3 m_e^{3/2} m_h^{1/2} \right)^{1/2} \right) \right]. \quad (8)$$

By plotting $\ln(T^2\tau)$ versus $1/kT$, the trap activation energy ΔE is extracted from the slope of the Arrhenius plot. The trap capture cross section can be calculated from the intercept with the vertical axis. As reported in [1] the (7) and (8) the ground state degeneracy factor g ($g = 2$ for donors, $g = 4$ for acceptors) have been included. This parameter doesn't affect the extraction of the trap energy but has an effect in the calculation of the trap's cross section. Clearly, the choice of (7) and (8) instead of (4) and (5) facilitates the calculation of the trap's energy level (eliminating the dependence to E_i) but these simplifications introduce an ambiguity in determining if the trap is a donor or an acceptor. Therefore LFN versus T cannot by itself perform an exact determination of the nature of the trap but can make precise results on the activation energy ΔE from the appropriate

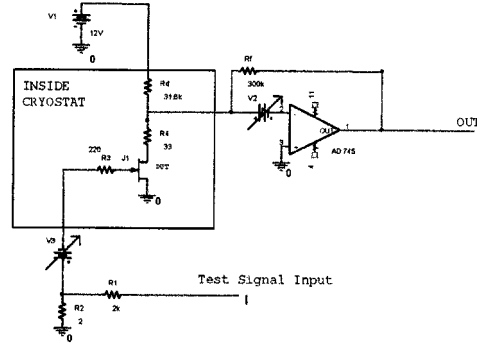


Fig. 1. Schematic diagram of the noise and transconductance measurement circuit.

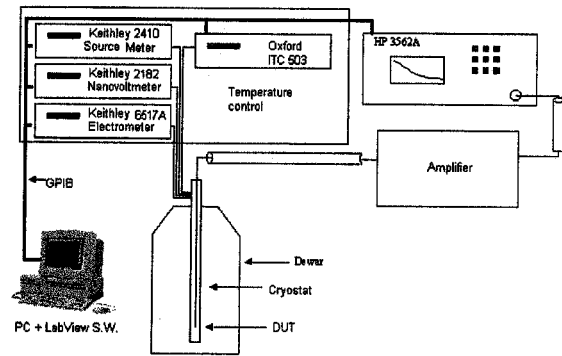


Fig. 2. Automatic system for noise measurement in the 4 to 300 K range.

band edge. In our work, we have extrapolated the nature of the traps correlating our measurements with the data reported in literature obtained with DLTS and other techniques performed on bulk Ge.

III. EXPERIMENTAL TECHNIQUES

We have developed an automatic system for noise measurement able to control the temperature within ± 5 mK in a temperature range of 4 to 300 K [11]. This system is based on an Oxford Compact VTI open cycle-continuous flow cryostat and various instruments interfaced via GPIB for temperature control and measurement. The software which performs the temperature regulation according to the proportional-integrative-differential (PID) algorithm has been developed using National Instruments Labview 5.1 as visual programming environment. The same tool was used to develop the software driver for the HP 3562A Dynamic Signal Analyzer. This instrument provides noise spectral measurements and the software developed performs a preliminary analysis of the devices under test. The device under test (DUT) is connected in a common source configuration in an open loop circuit, allowing simultaneous measurements of transconductance and noise (see Fig. 1) [12].

A block diagram of whole experimental setup is given in Fig. 2.

In previous works [1], [10], where LFN versus T spectroscopy was first implemented, low frequency noise was measured only at particular spot frequencies by using custom designed high order notch filter or a commercially available noise analyzer, which performs noise measurements at five spot

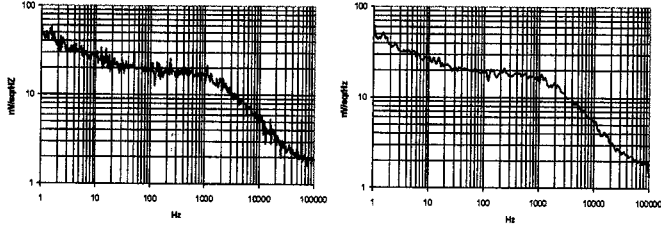


Fig. 3. Noise spectrum of Ge JFET sample A74G taken at 47 K before (top) and after (bottom) the data smoothing and filtering process. Lorentzian components can be recognized in the spectral shape.

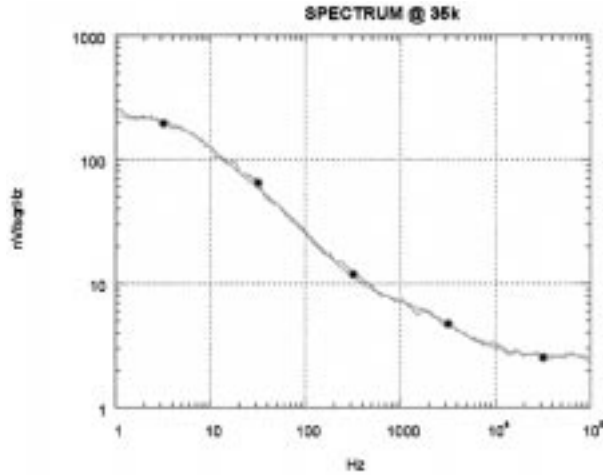


Fig. 4. Best curve fit superimposed onto the smoothed spectrum taken at 35 K (Ge JFET sample A74G).

frequencies simultaneously. Unfortunately this method is able to draw Arrhenius plots using only the same number of points as the number of spot frequencies where the noise is measured. To improve the LFN versus T technique, in our approach we have combined repeated noise spectral measurements in the range 1 Hz–100 kHz in five decades (80 pts/dec) taken at 500 mK per step with numerical calculations that, fitting the spectra, deliver the value of the G–R time constant as a function of the temperature. To perform this task, each spectrum (obtained by averaging eight records) is first pre-filtered to cancel the harmonics due to 50 Hz and RF pickup. The spectrum is smoothed using a five-channel window algorithm, as indicated in (9):

$$n_{\text{smoothed}}(i) = \frac{1}{16}n(i-2) + \frac{1}{4}n(i-1) + \frac{3}{8}n(i) + \frac{1}{4}n(i+1) + \frac{1}{16}n(i+2). \quad (9)$$

A comparison of a spectrum before and after the smoothing and filtering process is given in Fig. 3.

To extract the value of τ for each temperature, the smoothed spectra are fitted using the least-square estimator for a non-linear model (Levenberg–Marquardt algorithm), as shown in Fig. 4. The interpolation assumed four Lorentzian components plus white noise (10):

$$S(f) = \sqrt{w^2 + \sum_{n=1}^4 \frac{A_n \tau_n}{1 + (2\pi f \tau_n)^2}}. \quad (10)$$

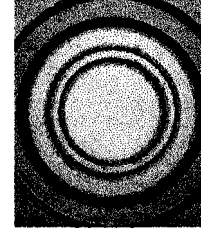


Fig. 5. Microphotograph of the circular Ge JFET investigated [5].

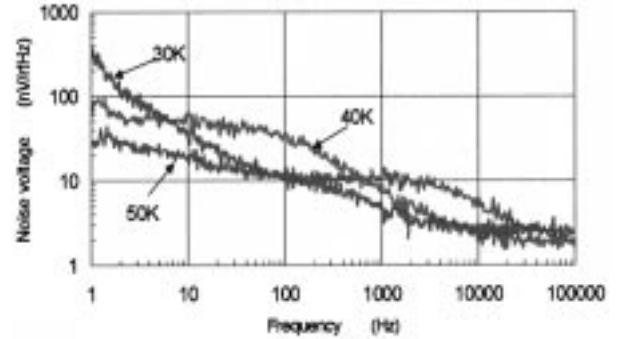


Fig. 6. Spectral measurement of Ge JFET A74G in the region 30 to 50 K.

The initial guess coefficients are previously extracted by the software which drives the HP3562 DSA. The same software provides also the filtering and smoothing process of the measured spectra.

Using this method the number of points that will form the Arrhenius plot is limited only by the resolution of the temperature controller that must keep the temperature stable during the spectral measurement process (15 min for each spectrum). In fact, as shown in (11) and (12), the slope of the Arrhenius plot is proportional to the trap energy but inversely proportional to the temperature and therefore is clear that the number of points of the plot increases when the temperature measurement step is decreased. Comparing to DLTS, our method fails where the device investigated shows a $1/f$ -like noise. This noise is the result of Lorentzians overlapping (that occurs when different G–R centers are simultaneously activated at the same temperature with similar defect concentrations) as demonstrated by Van Der Ziel [14].

IV. RESULTS AND DISCUSSION

The sample analyzed in this work was chosen for its strong Lorentzian spectrum rather than for exhibiting the lowest noise. In fact, other JFETs produced in the same or in previous batches show slightly different noise behavior at LN temperature. The Ge JFET A74G is an n-channel device, fabricated in circular geometry (Fig. 5). The gate length is 50 μm and the gate width is 2730 μm , for fabrication details refer to [5]. During the noise measurements the device was biased with a drain current $I_d = 330 \mu\text{A}$ and a drain-source voltage $V_{ds} = 1.2 \text{ V}$ for a total power dissipated $P = 400 \mu\text{W}$.

Before scanning the temperature in small steps we have performed a variable temperature noise characterization of the DUT, taking spectra every 10 K in the range 4 to 77 K.

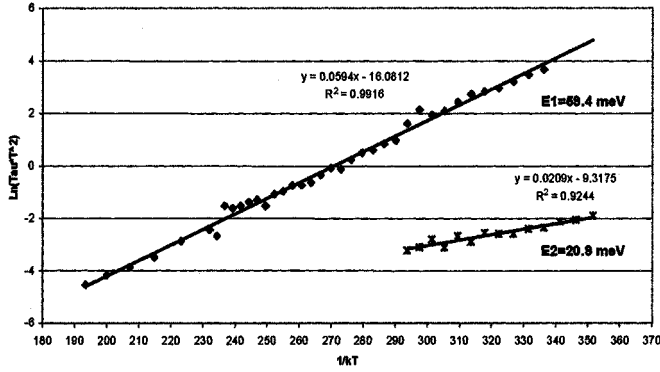


Fig. 7. Arrhenius plots showing two traps compatible with the presence of Be. The Arrhenius plot E_1 is obtained fitting the spectra measured in the range 30 to 60 K. In the 50 to 60 K range, the spectra are taken in step of 2 K.

Lorentzian spectra are more visible in the region 30 to 50 K as shown in Fig. 6.

To analyze more in detail the Lorentzian noise of the JFET sample A74G we have measured the spectra in the range 30 to 50 K with 500 mK per step. A limited number of spectra were taken in the 50 to 60 K range in step of 2 K. Processing the spectra as previously described, we have obtained different Arrhenius plots. Fig. 7 shows the results of a LFN versus T spectroscopy. The traps energies extracted from the slope are $E_1 = 59.4$ meV and $E_2 = 20.9$ meV. These energy levels are compatible with the acceptor levels introduced by Beryllium and reported by Milnes [15] and Sze [13].

In fact, previously measurements indicate the Be acceptor levels at 60 meV and 20 meV from the valence band edge. The cross-sections extracted from the intercept with the y -axis are $\sigma_1 = 1 \times 10^{-13}$ cm² and $\sigma_2 = 1 \times 10^{-16}$ cm² for E_1 and E_2 respectively. The presence of giant traps ($\sigma > 10^{-15}$ cm²) at very low temperature is predicted by Lax's cascade capture model [15], [16], assuming the emission of acoustical phonons while a carrier loses its energy before trapping. Another Arrhenius plot extracted from our measurement is shown in Fig. 8. The activation energy of $E_3 = 34.6$ meV is close to a copper single vacancy trap, measured at $E_v + 37$ meV using an optical DLTS (ODTLS) method performed on high purity (HP) germanium samples, as reported in [17].

The calculated cross section for the Cu trap is $\sigma_3 = 3 \times 10^{-16}$ cm². The presence of Cu impurities in germanium is not a surprise, its high diffusion coefficient makes this elements the main contaminants in HP detector grade Ge [17]. The other impurity energy level extracted from the Arrhenius plot E_4 ($E_4 = 79.4$ meV), shown in Fig. 8, is not reported in literature. The Lorentzian spectra might be caused by the presence of Gallium, in fact Sze indicates a deep impurity acceptor level due to Ga at 72 meV beyond the valence band of Ge. Another hypothesis, comparing our data with the energies extracted from the measurements on HP Ge, is the presence of Hydrogen. Its energy level in Ge is estimated in $E_v + 71$ meV [17]. The Arrhenius plots E_3 and E_4 are composed only by limited number of points and therefore the parameter extraction is less accurate, as discussed in Section V.

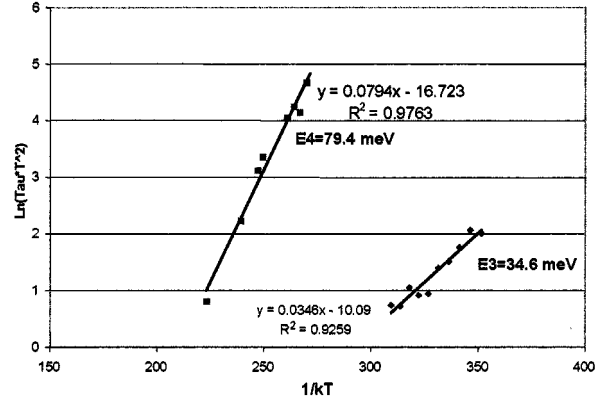


Fig. 8. Other Arrhenius plots extracted from the noise measurements of Ge JFET sample A74G. E_3 is compatible with a Cu trap. The energy extracted from the slope is $E_3 = 34.6$ meV. The energy level $E_4 = 79.4$ meV is not reported in literature. The associated impurity could be Ga or H.

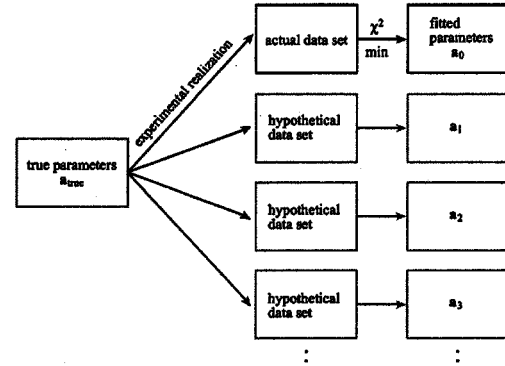


Fig. 9. Statistical universe of data sets from an underlying model [18].

V. ERROR ESTIMATION

As seen before, deep level traps investigation using LFN versus T technique requires repeated curve fitting on different spectral measurement, taken at various temperatures, to extract the characteristic time constant τ of the G-R process. Analytical evaluation of experimental errors is not simple to perform as this approach involves the calculations of errors due to noise voltage sampling, FFT processing and least squares curve fitting. To solve this problem an approach based on a statistical analysis shown to be helpful. Since every spectral measurement delivered by the automatic system described in Section III is performed in ≈ 15 minutes, we have chosen the method of generating synthetic spectra instead of repeating real measurement. Fig. 9 represents the “measure” of a parameters set in schematic way. The true physical parameters set \mathbf{a}_{true} is impossible to measure directly and therefore hidden from the experimenter. The realization of these true parameters is statistically distributed, with random measurement errors, as a measured data set $D_{(0)}$ known to the experimenter.

Once the data set $D_{(0)}$ is fitted using a least square algorithm a parameter set \mathbf{a}_0 is obtained. Because measurements errors have a random component, $D_{(0)}$ isn't a unique realization of the true parameters \mathbf{a}_{true} but there are infinite other realizations of the true parameter as “hypothetical data sets” each of which could be have been the one measured. Let us symbolize these by $D_{(1)}, D_{(2)} \dots$

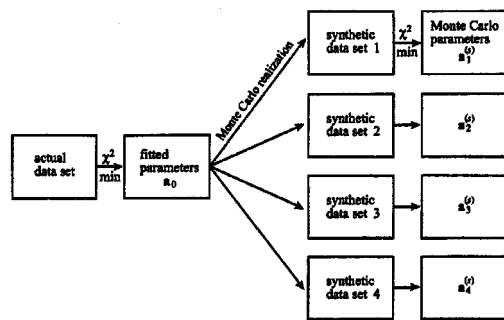


Fig. 10. Monte Carlo simulation of an experiment [18].

Each one would have given a slightly different set of fitted parameter $\mathbf{a}_1, \mathbf{a}_2, \dots$, respectively. Assuming that the difference $\mathbf{a}_{(i)} - \mathbf{a}_{\text{true}}$ is Gaussian distributed, we can evaluate the quantitative uncertainties in our experimental measurement \mathbf{a}_0 simulating repetitive measurements using a Monte Carlo method. Although the measured parameter set \mathbf{a}_0 is not the true one, let us consider a fictitious world in which it was the true one. Supposing that the shape of the probability distribution $\mathbf{a}_{(i)} - \mathbf{a}_0$ in the fictitious world is the same as the shape of the probability distribution $\mathbf{a}_{(i)} - \mathbf{a}_{\text{true}}$ in the real world, we are able to generate synthetic data sets Gaussian distributed around a reconstructed curve using \mathbf{a}_0 (Fig. 10).

The simulated data sets (let us call these sets $D_{(i)\text{sim}}$) must have the same numbers of measured points and the same values of all independent variables as the actual data set $D_{(0)}$. By construction these are supposed to have exactly the same statistical relationship to \mathbf{a}_0 as $D_{(0)}$ have to \mathbf{a}_{true} . Performing exactly the same fitting procedure for each $D_{(i)\text{sim}}$ as was performed to get the parameters \mathbf{a}_0 , we obtain the simulated measured parameters $\mathbf{a}_i^{(s)}$. Simulating enough data sets and enough derived measured parameters is reconstructed the statistical gaussian behavior of each parameter that compose \mathbf{a}_0 . Then, is possible to assume the standard deviation of the Gaussian distribution as uncertainty for each parameter in \mathbf{a}_0 [18]. Following the method shown before, we have verified first the Gaussian distribution of the HP 3562 FFT analyzer measurement process. To perform this task we have measured for 60 times the noise of an amplifier in the range 1 Hz–100 kHz in the same experimental conditions (room temperature). Every measured spectrum was obtained averaging eight records, as we have performed during the Ge JFET A74G noise measurement. Then we have plotted the distributions around the mean values of eight different spectral components (covering the region 1 Hz–10 kHz) verifying the Gaussian shape of each one and calculating the standard deviation (Table I).

These calculations yield an average standard deviation of 11% in the spectrum analyzer measurement process. This value was introduced in the Gaussian random generator during the creation of synthetic data sets. Using Labview we have designed a software tool able to generate synthetic spectra, composed of 80 points per decade as the measured one. Synthetic spectra are obtained introducing a Gaussian white noise in a reconstructed spectrum, created analytically from the parameter extracted from the fit of the measured one (Fig. 11).

TABLE I
STATISTICS OF ITERATED SPECTRAL MEASUREMENTS OF AN AMPLIFIER USING AN HP3562 (8 AVERAGES)

Frequency (Hz)	Mean of measured noise voltage, n. of samples=60, nV/sqrt(Hz)	Standard deviation	Standard deviation(%)
3.073	3.10	0.29	9.3
9.716	2.44	0.33	13.5
30.73	2.34	0.22	9.4
97.16	2.30	0.31	13.4
307.3	2.26	0.21	9.3
971.6	2.23	0.26	11.6
3073	2.22	0.21	9.4
9716	2.11	0.25	11.8

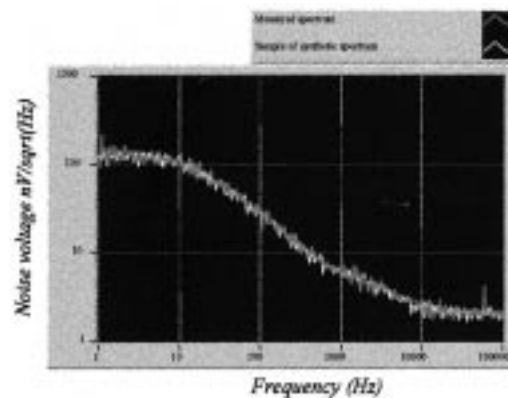


Fig. 11. Measured spectrum of Ge JFET A74G taken at 36.5 K superimposed to one sample of synthetic spectra generated using the Gaussian random generator.

The Gaussian random generator virtual instrument (VI), integrated within Labview programming environment, provides a noise pattern larger than 2×10^9 elements [19] and therefore it is suitable for our purpose. One of the problems calculating the uncertainty that affects G–R time constants depends on the shape of the measured spectra. When one and only one Lorentzian component is measured, the least-square fit algorithm easily delivers the parameters related to the single active trap plus white noise. But when two or more traps are activated simultaneously the spectral Lorentzian shape is less defined, decreasing the fit algorithm accuracy. Then, in error calculation we have chosen a worst-case approach, in fact we have estimated the error that affects the extraction of G–R time constant creating a set of synthetic spectra by choosing a real spectrum of the Ge JFETA74G measured at 36.5 K, that shows three lorentzian components analyzed in Section IV (Fig. 12).

Using the software previously described, 100 synthetic spectra of Ge JFET A74G are created simulating 100 measurements of the same device at 36.5 K. After a five channel smoothing process, the simulated spectra are fitted using a least-square Levenberg Marquardt algorithm integrated into a commercial package. The initial guess coefficients introduced in the fit algorithm are the same that were introduced during the extraction of GR time constants from the spectrum measured using the FFT analyzer. Assuming one standard deviation around the mean as uncertainty in the determination of τ values, the results for the analyzed traps are summarized in Table II.

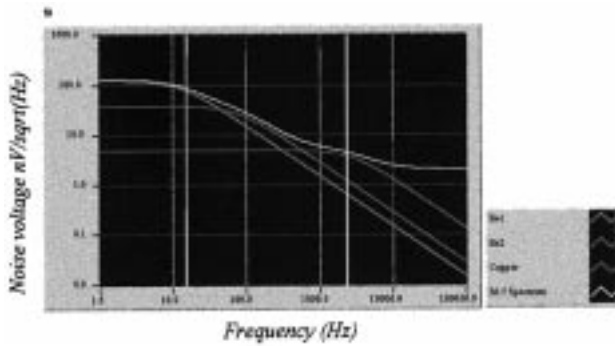


Fig. 12. Reconstructed spectrum of Ge JFET A74G at 36.5 K, showing three Lorentzian components.

TABLE II
RESULTS OF STATISTICAL ANALYSIS OF SYNTHETIC SPECTRA. THE SIMULATION RECONSTRUCTS A SPECTRUM TAKEN AT 36.5 K

	<i>Arrhenius plot E1</i>	<i>Arrhenius plot E2</i>	<i>Arrhenius plot E3</i>
<i>τ mean value (Sec.)</i>	0.013	5.81E-05	2.17E-03
<i>standard deviation (Sec.)</i>	0.001	5.3E-06	2.9E-04
<i>Stdev %</i>	8.15	9.1	13.7

TABLE III
EVALUATION OF ERRORS OF DEEP TRAPS PARAMETERS OBTAINED FROM LFN VS. T USING A MONTE CARLO APPROACH

<i>E1</i>	<i>E2</i>	<i>E3</i>	
0.0590	0.0208	0.0345	energy mean(eV)
0.000434	0.0013	0.0019	energy stdev(eV)
0.73	6.56	5.6	% energy error
1.08E-13	1.34E-16	3.26E-16	cross section mean(cm2)
1.36E-14	6.26E-17	2.34E-16	cross section stdev(cm2)
12.56	46.55	71.76	% cross-section error

The same method was used for determining the errors that affect the extraction of energies and cross-sections in the Arrhenius plot. We have developed a software that creates synthetic data sets for Arrhenius plots implementing two random generators, the first one generates the Gaussian distribution around every τ value using the standard deviation obtained previously, and the other one generates the Gaussian distribution of the error that affects the temperature measurements. Since the temperature is measured within an uncertainty of ± 5 mK in a range 4 to 300 K, its contribution determining the energy and cross section errors is negligible and therefore an overestimated error of $\pm 0.001\%$ is assumed in the whole measurement range (30 to 50 K). The software creates 5×10^4 synthetic Arrhenius plots for each trap, every plot is composed by the exact number of points extracted from the previous real noise measurements taken within 500 mK per step (33 points for Arrhenius plot E1, 14 points for E2, 10 points for E3, respectively).

The Arrhenius plot E_4 is obtained in a temperature range where some spectral measurements are taken with different temperature steps and therefore the error analysis is not performed.

Every Arrhenius plot is fitted on a straight line and the energy is extracted from the slope and the cross section is extracted from the intercept with the y -axis according to the (8).

The results are summarized in Table III.

VI. CONCLUSIONS

We have used low frequency noise versus temperature spectroscopy to investigate the noise on a recently designed Ge JFET. We have improved previous methodology measuring the whole noise spectrum in a range 1 Hz–100 kHz combined with nonlinear curve fitting, instead of analyzing the noise at fixed frequencies, as reported in previous works. The impurity levels extracted from the Ge JFET measurements are compatible with the Beryllium acceptor levels at 60 meV and 20 meV from the valence band. Other two traps are analyzed, showing a probable copper single vacancy at 34.5 meV from the valence band and another impurity level at 79.4 meV whose origin is still not clear.

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REFERENCES

- [1] F. Scholz and J. Roach, "Low frequency noise as tool for characterization of near-band impurities in silicon," *Solid State Electron.*, vol. 35, no. 4, pp. 447–452, 1992.
- [2] B. K. Jones, "Low frequency noise spectroscopy," *IEEE Trans. Electron Devices*, vol. 41, pp. 2188–2197, Nov. 1994.
- [3] P. V. Kolev, M. J. Deen, J. Kierstead, and M. Citterio, "Constant resistance deep-level transient spectroscopy in Si and Ge JFET's," *IEEE Trans. Electron Devices*, vol. 46, pp. 204–213, Jan. 1999.
- [4] R. Ward, R. K. Kirschman, M. Jhabvala, R. Babu, N. C. Das, D. V. Camin, and G. Pessina, "Development of cryogenic JFET's," *J. de Physique, Proc. WOLTE 3*, vol. Pr3-123, 1998.
- [5] R. R. Ward, R. K. Kirschman, M. D. Jhabvala, R. S. Babu, N. C. Das, D. V. Camin, V. Grassi, K. Kandiah, and J. J. Rosemberg, "Development of cryogenic Ge JFETs-III," in *4th Workshop Low Temperature Electron., ESA Proc.*, vol. WPP-171, 2000, pp. 105–111.
- [6] W. Shockley and W. Read, "Statistics of recombination of holes and electrons," *Phys. Rev.*, vol. 87, no. 5, pp. 835–842, 1952.
- [7] C. T. Sah, "Theory of low frequency generation noise in junction gate FET," *Proc. IEEE*, vol. 52, pp. 745–814, 1964.
- [8] J. W. Haslett and J. Kendall, "Temperature dependence of low frequency excess noise in junction gate FET's," *IEEE Trans. Electron Devices*, vol. ED-19, pp. 943–950, 1972.
- [9] B. Lengeler, "Semiconductor devices suitable for use in cryogenic environment," *Cryogenics*, pp. 439–439, Aug. 1974.
- [10] F. Scholz, J. Hwang, and D. Schroder, "Low frequency noise and DLTS as semiconductor characterization tool," *Solid State Electron.*, vol. 31, no. 2, pp. 205–217, 1988.
- [11] D. V. Camin, C. Colombo, V. Grassi, and G. Pessina, "Automatic system for DC and noise characterization of solid state devices in the range 4 K–300 K," in *4th Workshop Low Temperature Electron., ESA Proc.*, vol. WPP-171, 2000, pp. 151–155.
- [12] R. K. Kirschman, S. Lemoff, and J. Lipa, "Evaluation of GaAs FET's for cryogenic readout," *Proc. SPIE, Infrared Readout Electron.*, vol. 1684, p. 110, 1992.
- [13] S. Sze, *Physics of Semiconductor Devices*. New York: Wiley, 1981.
- [14] A. Van der Ziel, *Noise in Solid State Devices and Circuits*. New York: Wiley, 1986.

- [15] A. G. Milnes, *Deep Impurities in Semiconductors*. New York: Wiley, 1973.
- [16] M. Lax, "Giant traps," *J. Phys. Chem. Solids*, vol. 8, pp. 99–73, 1959.
- [17] A. Blondeel, P. Clauws, and D. Wincke, "Optical deep level transient spectroscopy of minor carrier traps in n-type HP Germanium," *J. Appl. Phys.*, vol. 81, no. 10, May 1997.
- [18] Numerical Recipes in C (2000). [Online]. Available: www.nr.com
- [19] *Labview Reference Manual*, National Instruments Corp., Austin, TX.



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and conducting laboratory work in many member countries. In 1984, he was appointed Director of the Interregional Course on Nuclear Electronics held in Vienna at the IAEA headquarters. Since 1985, he has been with the Physics Department and Istituto Nazionale di Fisica Nucleare (INFN), Milano, Italy. He participated from the very beginning in the development of cryogenic particle detectors in connection with an experiment on double-beta decay. Soon he started a research activity on cryogenic microelectronics oriented to applications in high energy physics experiments. He studied the cryogenic properties of GaAs MESFET technology and introduced the first low-noise cryogenic preamplifier operating down to 4 K followed by a fully monolithic version optimized for the LAr calorimeter of the ATLAS experiment at CERN. Since 1992, he has been an Associate Professor of nuclear electronics at the University of Milano and member of the Council for the Ph.D. in physics. His research interests are centered on low noise electronics and cryogenic microelectronics for high-energy and astroparticle physics experiments. He is author or coauthor of over 150 papers related to his research.

Mr. Camin is a member of the Advisory Committee of the European Workshop on Low Temperature Electronics.

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Piano finanziario globale di spesa

									<i>In KEuro</i>
ANNI FINANZIARI	Miss. interno	Miss. estero.	Materiale di cons.	Trasp. e Facch.	Spese Calc.	Affitti e Manut. Appar.	Mater. inventar	Costr. appar.	TOTALE Compet.
2004	5	8	12.5	0	0	0	25	0	50.5
2005	5.0	7.0	10.0	0.0	0.0	0.0	5.0	0.0	27.0
2006	5.0	8.0	7.0	0.0	0.0	0.0	0.0	0.0	20.0
TOTALI	15,0	23,0	29,5				30,0		97,5

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno 2004

Struttura
MI

Codice	Esperimento	Gruppo
	LIGHT	5
Resp. loc.: Daniel Camin		

COMPOSIZIONE DEL GRUPPO DI RICERCA

N	RICERCATORE Cognome e Nome	Qualifica				Affer. al gruppo	%	N	TECNOLOGI Cognome e Nome	Qualifica			%
		Dipendenti		Incarichi						Dipendenti	Incarichi		
		Ruolo	Art. 23	Ricerca	Assoc.					Ruolo	Art. 23	Ass. Tecnol.	
1	Camin Daniel Victor			P.A.		2	40						
2	Grassi Valerio				AsRic	5	60						
								Numero totale dei Tecnologi				0	
								Tecnologi Full Time Equivalent				0	
N	TECNICI Cognome e Nome	Qualifica				%							
		Dipendenti		Incarichi									
		Ruolo	Art. 15	Collab. tecnica	Assoc. tecnica								
Numero totale dei ricercatori						2	Numero totale dei Tecnici						0
Ricercatori Full Time Equivalent						1	Tecnici Full Time Equivalent						0
SERVIZI TECNICI								Annotazioni:					
Denominazione						mesi-uomo							

Osservazioni del direttore della struttura in merito alla disponibilità di personale e attrezzature

