EE

TNPI 93-2

НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ ТОМСКОГО ПОЛИТЕХНИЧЕСКОГО УНИВЕРСИТЕТА

STUDY OF TEMPERATURE DEPENDENCE OF LIGHT YIELD FROM $NaBi(WO_4)_2$ CRYSTALS

C. Yu. Amosov, B. N. Kalinin, Yu. F. Krechetov,
A. V. Moiseenko, G. A. Naumenko, A. P. Potylitsyn,
V. M. Samsonov*), V. P. Sarytchev, Ye. N. Shuvalov,
J. P. Solodov*), and Ye. A. Vznuzdaev*)

---

*) St. Petersburgh Nuclear Physics Institute
of the Russian Academy of Sciences

ПРЕПРИНТ 2/93
June 1993

ТОМСК

STUDY OF TEMPERATURE DEPENDENCE OF LIGHT YIELD FROM $NaBi(WO_4)_2$ CRYSTALS

C. Yu. Amosov, B. N. Kalinin, Yu. F. Krechetov,
A. V. Moiseenko, G. A. Naumenko, A. P. Potylitsyn,
V. P. Sarytchev, and Ye. N. Shuvalov
institute for Nuclear Physics
Tomsk Polytechnical University,
Tomsk, Russia

Ye. A. Vznuzdaev, V. M. Samsonov, and J. P. Solodov
St. Peterburh Nuclear Physics Institute of the Russian
Academy of Sciences
St. Peterburh, Russia

Abstract

We have measured the temperature dependence of light yield and the scintillation time structure from $NaBi(WO_4)_2$ crystals bombarded by 500 MeV electrons. It have shown this crystals tend to exhibit scintillator properties as the samples temperature is decreases. The light yield increases by more then one order of magnitude as the temperature falls from the room level to that of liquid nitrogen. The scintillation time structure has a complicated pattern. The slow luminescent component ($\tau = 30$ns) is present in the spectrum.

1. Introduction

Within the framework of the design stage in the experiments on a new generation accelerators, such as SSC, LHC and UNK, recent years have seen vigorous scientific efforts made to research and develop improved materials for fast radiation-resistant electro-magnetic calorimeters. A most complete review of the ongoing developmental work was done at the recent workshop «Crystal-2000» [1].

One of the most promising candidates is $NaBi(WO_4)_2$ tungstate crystal (NBW) with the density $\rho=7.57$ g/cm^3, radiation length X_0 = 1.01cm and Molier radius R_m =2.4cm [2-6]. NBW exhibits high radiation resistance and manufacturability.

However, there seem to be a certain ambiguity concerning the interpretation of the NBW properties. For example, it was shown by Samsonov et al. [2] and Kachanov et al. [3] that NBW materials used in the experiments have proven to be Cherenkov radiation at room temperature whereas Korzhik et al. [4] and Nagornaya et al. [5] observed the intrinsic luminescence with characteristic luminescence times on the order of a few nanoseconds.

Our experiments was aimed at studying the intrinsic luminescence from NBW samples. We proceeded from the well-known fact that most of tungstates and molybdates (tungstate analogues) did not scintillate at room temperature while becoming good scintillators at low temperature [7, 8]. E. g., similar properties are demonstrated by $NaBi(MoO_4)_2$ [9], an isostructural compound for NBW. In view of this circumstance we decided to look at luminescence from NBW crystal cooled to the liquid nitrogen temperature.

The experiments were performed using a secondary electron beam from the Tomsk synchrotron. The electron energy could be varied from 20 to 700 MeV and the energy spread was about 2%.

2. The Experimental Setup

The layout of the experiment is shown in Fig.1. A 500 MeV electron beam passes through plastic scintillation counters S1 and S2, where a «trigger» pulse is formed by means of coincidence circuit C1 and then hits at the centre of the major face of NBW sample (24S24S55mm^3) (1) through window (2) of vacuum chamber (3). A beam size of 5S5mm^2 before the crystal was determined by the dimensions of scintillators of counter S2. All the crystal surfaces except for one of the end faces are surrounded by a reflector made of aluminium mylar. Light enters FEU-130 type photomultiplier (PMT) (4) placed at 9cm from the sample. FEU-130 is sensitive to light in the 200-650nm range and shows good one-electron performance. The PMT voltage divider was chosen so as to provide a high peak-to-valley ratio in the one-electron mode. Variable aperture (5) is placed between the sample and PMT to provide single photon-counting capability for measuring the time structure of light emission from the crystal.

In the vacuum chamber the sample is positioned on copper cooler (6) and is enclosed, except for the end faces, in a copper housing. The latter is in a thermal contact with the cooler to provide uniform cooling of the sample. Electric heater (7) mounted on the cooler provides constant temperature (±2K) at a given level in the 80-400K range. The temperature is controlled within ±0.1K by two carbon resistors (8) of TVO type placed on the sample and cooler.

To avoid thermal stress cracking of the sample the crystal is allowed to cool slowly (< 0.5K/min) by pumping through the cooler volume of nitrogen from Dewar flask (9). The flask is fitted with internal electric heater (10) and stopper (11) to provide nitrogen flow induced by excess vapour pressure in the flask. To avoid outward sweating, window (12) is blown over with nitrogen gas also pumped from flask (9). Resistance of the temperature sensors (8) is measured by digital volt-ohmmeter of F30 type controlled by a computer via MUF30M-type driver. The sensors are alternatively connected to volt-ohmmeter by means of RM750 type relay multiplexer. The latter also controls turning-on and off of heater power supply units in the vacuum chamber and Dewar flask.

3. Measurement Procedure

We have studied the temperature dependence of NBW crystal light yield and the time structure of light emission at room temperature and at 95K. The relative light yield was measured by charge-to-digit convertor CDC driven by a 1 μs «trigger» pulse. We have also carried out a test where the NBW crystal was replaced by a TF-5 lead glass sample (24S24S70mm^3) with polished surfaces, other conditions being equal. The resulting spectra minus the «pedestal» at 290 and 95K are shown in Fig. 2. As it was to be expected, the spectra are the same because TF-5 is not a scintillator and the Cherenkov radiation is a independent of the radiation temperature. Light yield spectra for NBW sample are shown in Fig. 3. Fig. 4 is a plot of average of light yield versus the crystal temperature, taking into account the light detection efficiency. At 90K the NBW light yield makes up about 2% of that from NaI(Tl). We are not aware of the temperature and light wavelength dependencies of the emission spectrum, except for the portion of spectrum virtually due to Cherenkov radiation. Therefore, the relative light yield given in Fig. 4 will be slightly changed, taking into account the spectral response of PMT used and variations of the light spectrum. Our previous measurements using the same instrumentation and a 19S19S19mm^3 NBW crystal revealed similar temperature dependence of the light yield.

The time structure of light yield was measured by time-to-digit convertor (TDC) for a one-electron operation of PMT (see Fig. 1). The single photon counting mode was achieved by choosing aperture size (5) so that the count of the coincidence circuit C2 was reduced to one-fiftieth of its value with the unblocked aperture. Measurement of the amplitude spectrum have shown that its major part falls at the region of the one-electron peak. The 4ns time resolution was primarily due to high-frequency influence from the synchrotron. Distribution of the events in the one-electron pulse arrival time (time form of light yield) is shown on Figs. 5 and 6 for sample temperatures of 290 and 95K. It is evident from the plots that at room temperature the emission spectrum is determined by Cherenkov radiation and the spectral broadening is generally due to the time resolution of the instrumentation used. At 95K the spectrum also exhibits a long scintillation «tail». In addition to Cherenkov radiation we have found a comparatively short light component with the average decay time $\tau_1 = 30$ns and the long wavelength component with $\tau_2 = 450$ns. In doing so, use was made of the least-square method. The light quantity ratio for the two components was about 1. Unfortunately, the statistical data available precluded us from making definite estimations.

4. Conclusions

The foregoing investigations have shown that NBW crystal tends to exhibit scintillator properties as the sample temperature is decreased. The light yield increases by more than one order of magnitude as the sample temperature falls from the room level to that of liquid nitrogen. The time structure of scintillation has a very complex pattern. Notice should be made of the presence of the slow luminescent component in the spectrum.

Our further work will address the problem of obtaining adequate statistics for the time spectrum of scintillation and of measuring the spectral distribution of light from the crystal.

Assistance of G. I. Ivanov in the preparation of the instrumentation is gratefully acknowledged.

References

1. Programme of the International Workshop on Heavy Scintillators for Scientific and Industrial Applications, Chamonix France, Sept. 22-26, 1992.
2. V. Samsonov et al., R&D on $NaBi(WO_4)_2$ cr [illegible] high energy physics EM-calorimeters, ibid.
3. V. Kachanov et al., 26-GeV electron beam test results of two EM-calorimeter prototypes made of heavy crystal $Gd_3Ga_5O_{12}$ and $NaBi(WO_4)_2$, ibid.
4. V. Korzhik et al., New fast and heavy $NaBi(WO_4)_2$ scintillator: spectroscopy and radiation resistance, ibid.
5. L. Nagornaya et al., Fast scintillators based on large heavy tungstate single crystals, ibid.
6. V. Selivanov et al., Fast and heavy scintillators based on $NaBi(WO_4)_2$, ibid.
7. W. van Loo. Phys. Stat. Sol. (a) 28, 227 (1975).
8. F. A. Kroger. Some aspects of the luminescence of solids, Elsevie Publishing Company Inc, NY, 1948
9. V. Ye. Karapetyan and A. V. Morozov. Izv. Akad. Nauk SSSR, Ser. Inorganic Mat., 4(11), 2039 (1968).

Figure Captions

Fig. 1 The experimental layout.
S1 and S2 — scintillation counters; F — pulse former; FD — former-discriminator of pulses; C1 and C2 — circuit schemes; 1 — NBW sample; 2 and 12 — windows of the vacuum chamber 3; 4 — FEU-130 photomultiplier; 5 — variable aperture; 6 — cooler; 7 and 10 — heaters; 8 — temperature sensors; 9 — Dewar flask; 10 — Dewar flask 9 stopper; F30 — digital volt-ohmmeter; MUF30 — volt-ohmmeter driver; RM750 — relay multiplexer; CDC — charge-to-digit convertor; TDC — time-to-digit convertor; C — binary counters.

Fig. 2 FEU-130 signal amplitude distribution for study a TF-5 lead glass sample at 290 and 95K.

Fig. 3 Light yield spectra for NBW sample.

Fig. 4 Dependence of light yield versus the crystal temperature.

Fig. 5 Time structure of light yield for NBW sample at 290K.

Fig. 6 Time structure of light yield for NBW sample at 95K.

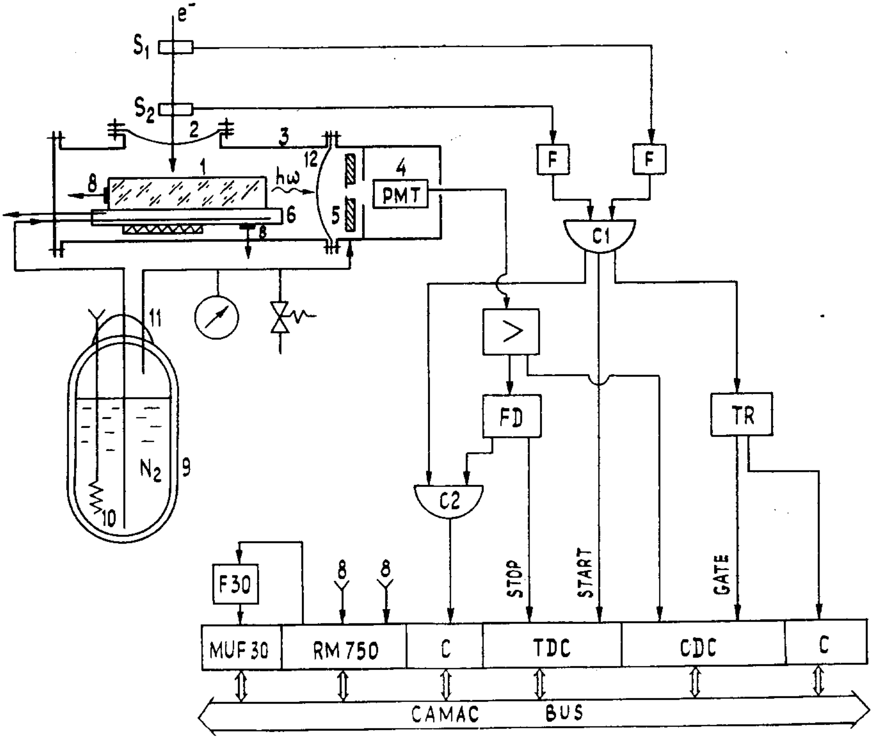

Fig.1

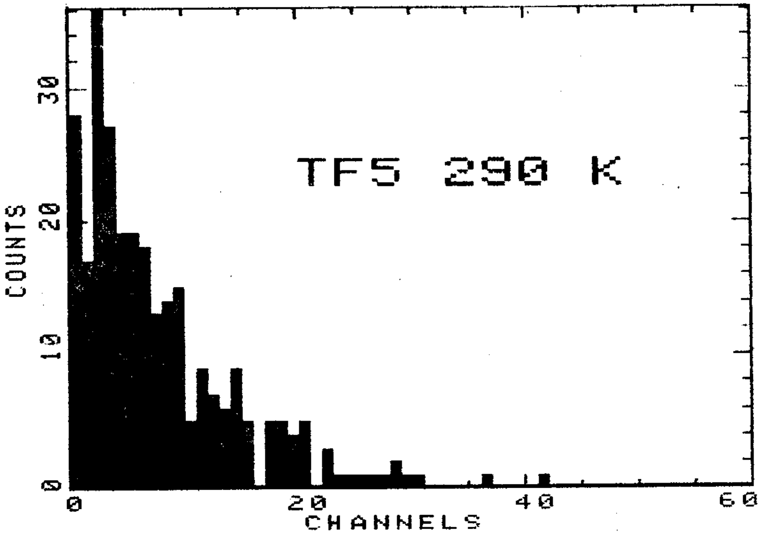
TF5 290 K
COUNTS
0
10
20
30
CHANNELS
0
20
40
60

FIG.2.A

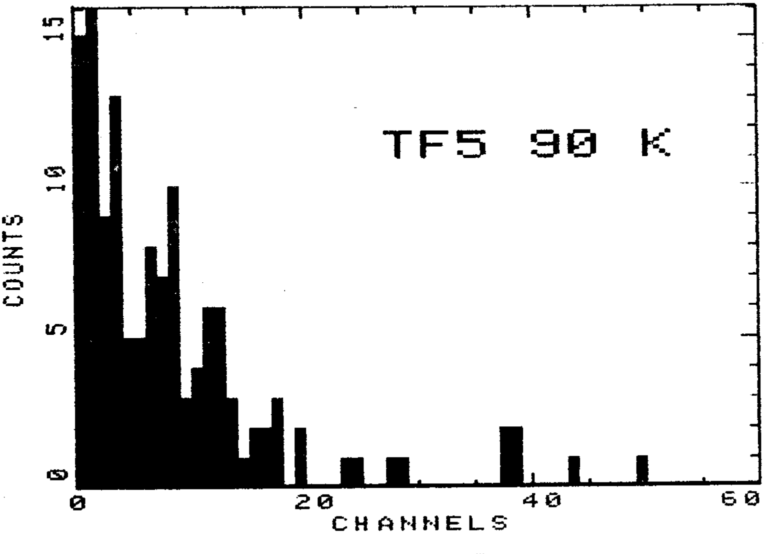
TF5 90 K
COUNTS
0
5
10
15
CHANNELS
0
20
40
60

FIG.2.B

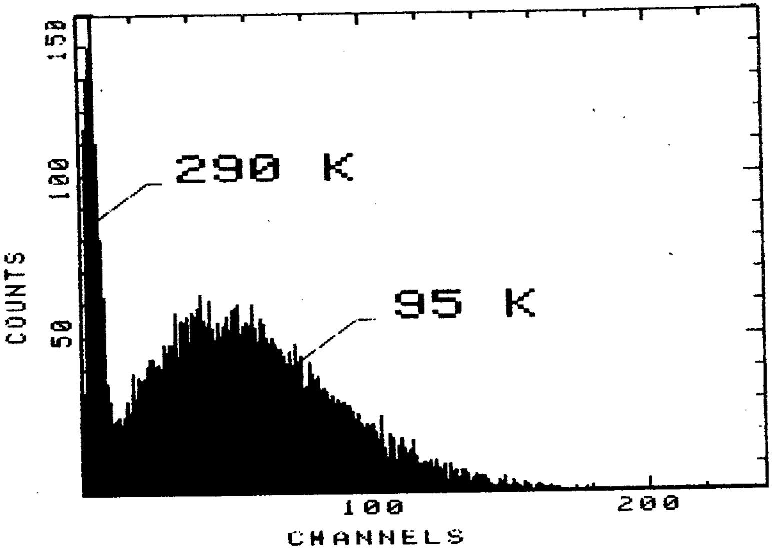
150
100
COUNTS
50
290 K
95 K
100
200
CHANNELS

FIG.3

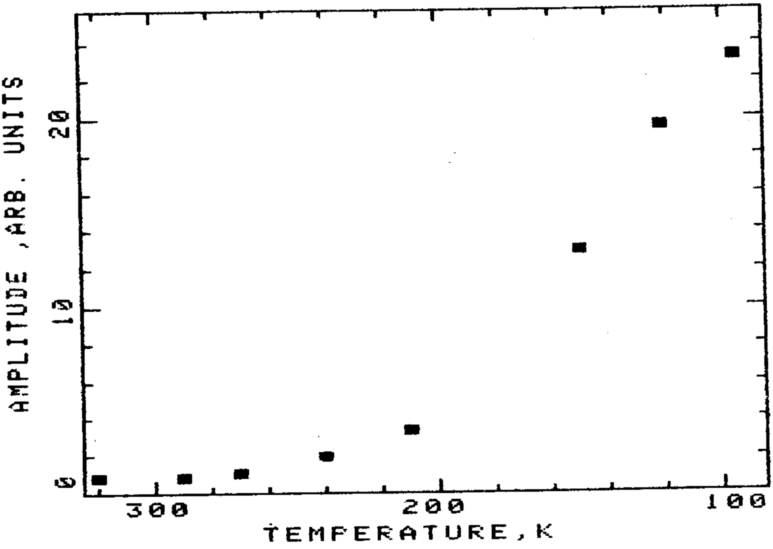
AMPLITUDE ,ARB. UNITS
20
10
0
300
200
100
TEMPERATURE,K

FIG.4

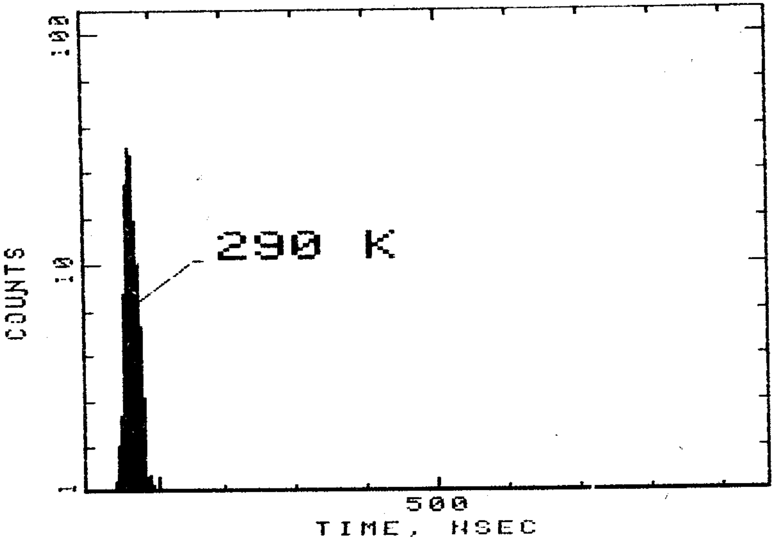
100
10
1
COUNTS
290 K
500
TIME, NSEC

FIG. 5

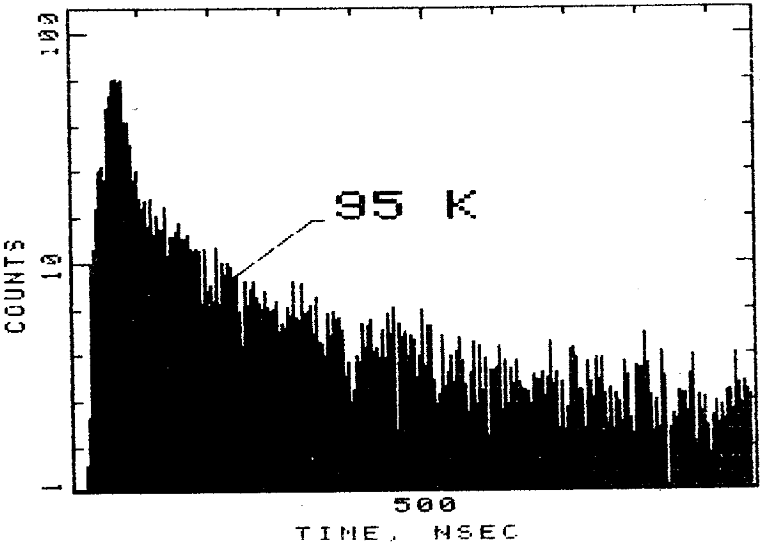
100
10
1
COUNTS
95 K
500
TIME, NSEC

FIG 6