Quality Assurance of lead tungstate crystals

1. PbWO4 crystal quality specifications

Crystal specification parameters, NPS requirements, methods used in the characterization and availability of the instrumentation at different institutions.

Parameter	Unit	NPS Required	Inform. Source	Institutions
Light Yield (LY) at RT (90% within 100 ns gate at RT, for all sides polished crystals)	pe/MeV	≥15	Light yield measurement with Na-22 or Cs-137 source or cosmics in temperature-controlled darkbox	CUA IPN-Orsay
LY uniformity between blocks	%	10%	Same as above	CUA IPN-Orsay
LY(100ns)/LY(1μs)	%	>95	Same as above, but with different gate widths	CUA IPN-Orsay
Longitudinal Transmission at λ=360 nm at λ=420 nm at λ=620 nm	 % % %	 ≥35 ≥60 ≥70	Perkin-Elmer Lambda 950 Perkin-Elmer Lambda 750 Varian Cary 5000 Ocean Optics Fiber spectrometer	CUA/VSL IPN-Orsay
Transverse Transmission and LY uniformity along crystal	%	10	Perkin-Elmer Lambda 950 Perkin-Elmer Lambda 750 Varian Cary 400 Ocean Optics Fiber spectrometer	CUA/VSL IPN-Orsay
Inhomogeneity of Transverse Transmission Δλ at T=50%	nm	≤5		
Induced radiation absorption coefficient Δk at λ=420 nm and RT, for integral dose >100 Gy	m^{-1}	<1.0	Faxitron CP 160 Co-60 source Electron beam	CUA/VSL IPN-Orsay Giessen U. IAC
Mean value of dk	m^{-1}	≤0.75		
Tolerance in Length Tolerance in sides	μm μm	≤±150 - ≤±50	Laser based measurement	JLab CUA
Surface polished, roughness Ra	μm	≤0.02	XRD, Raman microscope, AFM	CUA/VSL
Tolerance in Rectangularity (90°)	degree	≤0.1		JLab CUA
Purity specific. (raw material)			ICP-MS, ICP-ES, DCP-ES, MS, GC, IC, XRF, FT-IR, LA-ICP-MS	CUA/VSL company

Mo contamination	ppm	<1	ICP-MS, ICP-ES, DCP-ES, MS, GC, IC, XRF, FT-IR, LA-ICP-MS	CUA/VSL
La, Y, Nb, Lu contamination	ppm	≤40	ICP-MS, ICP-ES, DCP-ES, MS, GC, IC, XRF, FT-IR, LA-ICP-MS	CUA/VSL

In addition to the specification shown in Table 1, crystals should have no visible cracks on the chamfers prolonging in to the crystal. Either exist should be not more than 0.5 mm deep.

2. Experimental investigations

a) Initial inspection and labeling (JLab)

The initial inspection upon arrival will include a visual inspection checking for the labeling of the crystals and overall condition of the crystal (no visible cracks or cloudiness). Longitudinal and transverse dimensions of the crystals will be measured using a laser setup(?) at JLab. The roughness will not be inspected during initial inspection as the crystals are not specified to have focusing properties.

b) Optical transmission (CUA/IPNO)

The optical transmission will be measured for all crystal samples, which are polished on all surfaces. At CUA, the measurements will be performed using a double-beam optical spectrometer with integrating sphere (Perkin-Elmer Lambda 950) in the range of wavelengths between 200 and 900 nm. The reproducibility of these measurements is better than 0.2%. At IPN-Orsay, the measurements will be carried out either with a spectrophotometer (Varian Cary) or a fiber spectrometer. The optical transmission will be measured along all three dimensions. The homogeneity of the crystal will be investigated based on the variation of the transverse optical transmission. A quality parameter that characterizes the band edge absorption of the crystal can be defined as the maximum variation of the wavelength at a transmission value of T=50% along the length of the crystal. In addition, the maximum % deviation of the transverse transmission from the value measured at the center can be used. The transverse optical absorbance of all crystals, as well as their longitudinal transmission, will be measured as function of wavelength in order to fully characterize their quality.

c) Luminescence yield, temperature dependence and decay kinetics (CUA/IPNO)

At CUA, the crystals will be wrapped in three layers of Teflon foil and optically coupled to the entrance window of a 2-inch photomultiplier tube (Photonis XP2262) using Bicron BC-630 optical grease. The anode signals are directly digitized using a charge sensitive ADC (LeCroy 2249W) with integration gates between 100 ns and XX ns, to investigate the contribution of slow components. The setup is operated inside a temperature-controlled dark box, which provides for temperature accuracy and stability on the order of better than 1°C. The light yield will be determined using a ^{22}Na source emitting back-to-back photons of 0.511 keV. In a separate measurement, the response to a single photoelectron (pe) will be determined to calibrate the signal amplitude above the pedestal in units of photoelectrons. The measurement setup at IPN-Orsay is similar, but uses a Cs-137 source. The response will be measured at three different temperatures of 0°C, 10°C and 18°C.

d) Radiation resistance tests with 160 kV X rays (CUA)

Using the cabinet X-ray (Faxitron CP160) available at CUA, the radiation hardness of the crystals will be investigated. The optical transmittance will determined before and after irradiation with an integral dose of 30 Gy imposed within an irradiation period of 10 minutes. The crystals will be kept light tight during and after irradiation until the transmission measurement commences. The measurement will be performed no later than 30 minutes after the end of the irradiation procedure at room temperature. To extract the wavelength dependent change in transparency and to take the absolute crystal dimensions into account, the absorption constant will be calculated. The effect due to radiation damage is expressed by the change of the absorption constant in units of inverse meters.

e) Radiation resistance tests with Co-60 source (IPNO)

Through collaboration with the Laboratoire de Chimie Physique at Orsay the group has access to a panoramic irradiation facility based on 3000 Cu Co-60 sources. This facility can provide dose rates ranging from 6 to 5000 Gy/h. Thus, high total doses can be accumulated in a short period of time and the effect of different photon irradiation rates can also be studied. In addition, IPN-Orsay houses several beam facilities that can be used to further study the effects of radiation on PbWO4 blocks. Firstly, a 50 MeV electron facility (ALTO) can provide up to 1 microA of electrons that can complement the irradiation tests made with photon sources.

f) Chemical Analysis (CUA/VSL)

The chemical composition of the crystals will be investigated using a combination of standard chemical analysis methods including XRay Fluorescence (XRF) and ICP-MS.

Conditions for crystal certification and acceptance

The Neutral Particle Spectrometer (NPS) collaboration is responsible for the certification of the crystals delivered by SICCAS. The NPS collaboration is not obliged to disclose the results of the certification to SICCAS, except for rejected crystals. The result of the certification will be summarized in a certification protocol including the following parameters

- Individual number corresponding to the SICCAS number
- Dimensions of the crystal
- Visual inspection report
- Optical properties of the crystal:
    - T, % at 360nm,
    - T, % at 420nm,
    - T, % at 620nm,
    - Scintillation yield
    - Scintillation kinetics
    - Non-uniformity of the transversal transmission
- Radiation hardness (if measured)