AUTOMATIC PHOSPHATE GLASS DOSIMETRY SYSTEM USING PULSED UV LASER EVALUATION

E. Piesch, B. Burgkhardt and M. Vilgis
Kernforschungszentrum Karlsruhe, Hauptabteilung Sicherheit
Federal Republic of Germany

T. Omori and T. Ikegami
Toshiba Glass CO. LTD., Tokyo
Japan

INTRODUCTION

Photoluminescent detectors became once more attractive in routine photon dosimetry after N_2 lasers of high intensity and reproducibility are commercially available. The UV excitation with pulsed laser, in particular, reduces the pre-dose reading by two orders of magnitude and makes the previously used glass cleaning procedure unnessecary. Flat phosphate glass dosemeters with energy compensation filters have now the advantages of measuring low doses in the 10 μSv range and being practically independent of energy and the direction of the radiation incidence down to photon energies of 10 keV.

On the basis of long-term routine experience with photoluminescence dosimetry (PLD) systems (1,2) and previously performed investigations using flat glass dosemeters (3) in combination with the Toshiba reader FGD-8 with pulsed UV-laser excitation (4), Toshiba Glass and KfK recently agreed in a joint cooperation program to design and build-up a modern automatic read-out system using pulsed UV laser excitation. A prototype of the commercial automatic read-out system FGD-10 was built-up at the end of 1987. The full read-out system makes use of a dosemeter encapsulation unlocked and opened automatically within the reader. A microprocessor controlled evaluation technique allows the flexible change of the read-out procedure by the choice of five different read-out modes, the simultaneous indication of different dose quantities and the automatic exchange of high dosed by annealed glass cards as well as a long-term data storage of the accumulated dose.

DOSEMETER AND READ-OUT SYSTEM

The slide type flat glass dosemeter capsule (size 4x3x0.8 cm^3) has been developed for the automatic reader using UV laser pulse excitation (Fig. 1). Toshiba FD-P16-7 glass element (size 16x16x1.5 mm^3) is fixed in a stainless steel card bearing the card No. (hole code). The glass card is housed in the plastic capsule having the energy compensation filters consisting of perforated tin filters of 0.75 mm thickness. The capsule is locked by a magnetic latch and can be released only in the read-out instrument. The capsule is marked with ID No. (bar code).

Toshiba FGD-10 is a full automatic PLD read-out system. The mechanical unit (Fig. 2, A) allows by magazine supply the continuous reading of up to 500 dosemeters as well as the automatic exchange of high dosed by annealed glass cards, the opening and closing of dosemeters, an auto-reading of ID No. for capsules and cards. The optical part (Fig. 2, B) consists mainly of the pulsed nitrogen gas laser, optical filters and diaphragm in front of the glass and the photomultiplier (PM), respcetively. The size of the last one is automatically exchangable to indicate different dose quantities. Eu-doped calibration glasses and dosed reference glasses are used for the continuous calibration of the read-out system and the laser pulse intensity, respectively.

In order to suppress the pre-dose reading caused by primary fluorescence in the glass and dirtyness on the glass surfaces the measurement unit (Fig. 2, C) makes use of the following technique: After the pulsed UV excitation of 5 ns and a delay time of about 2 μs the microprocessor supported evaluation separates a short-term and long-term luminescent component which are integrated in the periods (2-22) μs (area F_1) and in the period (40-60) μs (area F_2), respectively. The actual F_2 value serves for the correction of pre-dose. The difference $(F_1\text{-}a\cdot F_2) = M$, indicated by the display, is then proportional to the dose. During read-out of annealed glasses the batch dependent factor „a" is set automatically that just positive pre-dose values are indicated. The reader allows the choice of 10 to 50 pulses per read-out, resulting for the higher pulse frequency in a lower random error of measurement in particular in the dose range below 0.5 mSv.

All readings are carried out full automatically by control with a computer (Fig. 2, E), which fulfills any functions in 5 different modes of read-out: data processing, drawing up of documents, data filing and transmitting to a host computer. The on-line desk computer/printer indicates card and capsule number, the pre-dose, the dose, the daily accumulated dose between entrance/exit control and the total accumulated dose for a dosemeter card and capsule. Personal data can be stored for a group of 10 000 dosemeters/persons.

ENERGY AND ANGULAR RESPONSE

The size of the diaphragm in front of the PM and thus the ratio of the tin and plastic covered glass volume may be changed. By this technique different dose quantities may be indicated, for instance the directional independent dose quantity „exposure" X free in air and the new directional dependent dose quantity H'(10) on the phantom (Fig. 3). Using for calibration a water-filled sphere phantom of 30 cm diameter which simulates the ICRU sphere, the energy dependence has been found to be within ±10 % in the photon energy range 10 keV - 1.3 MeV. On the basis of a free air calibration the same glass dosemeter indicates the dose quantity exposure within ±20 % above a photon energy of 25 keV. For these dose quantities and energy ranges, in personnel dosimetry the angular reponse has been found to be within ± 30 % in the angular range 0° to 60°. For an application in environmental monitoring the angular response in isotrop fields is simulated by rotation in two axis.

Furthermore, the ratio of the PL intensity measured in the glass volumes behind the plastic and tin filter, respectively, may be used as an estimate of radiation quality in the photon energy range below 100 keV.

DOSIMETRIC PROPERTIES

The lower detection limit H_{LDL} defined as two times the standard deviation of the pre-dose of glasses unirradiated was found to be 30 µSv and 7 µSv for 10 laser pulses and 200 laser pulses per read-out, respectively. Assuming a monitoring period of 1 month, for instance, the dosemeter may thus indicate the natural radiation background H_{nat} = 60 µSv with an random uncertainty (1 σ value) of ± 15 % and together with an additional occupational dose of 50 µSv within ±4 %.

After a total accumulated dose of 3 mSv the lower detection limit for the estimation of additional doses is H_{LDL} = 0.1 mSv. On this basis the dosemeter may accumulate H_{nat} over a period of 4 years before an annealing procedure is necessary. For occupational annual doses below the maximum permissible annual dose limit a one-year dose accumulation in personnel dosimetry seems to be appropriate to estimate the annual dose of a person with the lowest random uncertainty of better than ± 5 % for the total dose.

Tab. 1 compares the basic dosimetric properties of the PLD system with those of a TLD system. Assuming also for the TLD system an oven annealing and an individual pre-dose subtraction the pre-dose values, the lower detection limit and the random uncertainty in the linear dose range are comparable for both systems. The PLD system, however, offers batch uniformity in pre-dose and response and thus corrections of the individual response are not nessecary). The read-out of glasses can be repeated. A high energy threshold, one of the main drawback of phosphate glasses in the past, turned out to be superior to that of LiF, above all with respect to the indication of the new dose quantities. Temperature during exposure and storage does not seriously affect the reading and the dose stability with respect to environmental effects is higher than those for LiF.

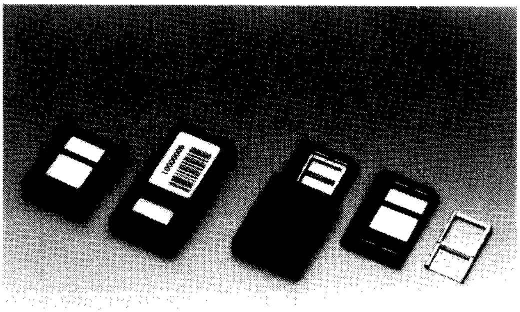


Fig. 1 SC-1 flat glass dosemeter

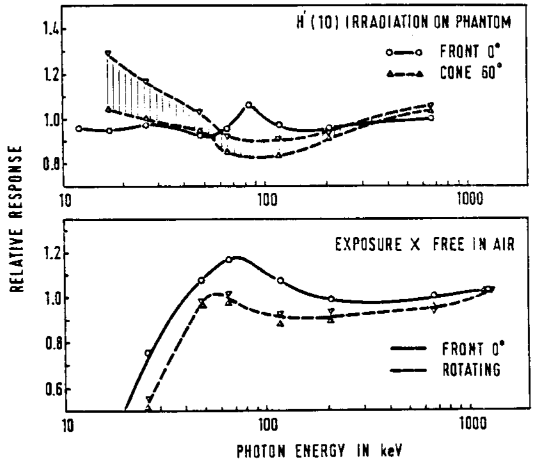
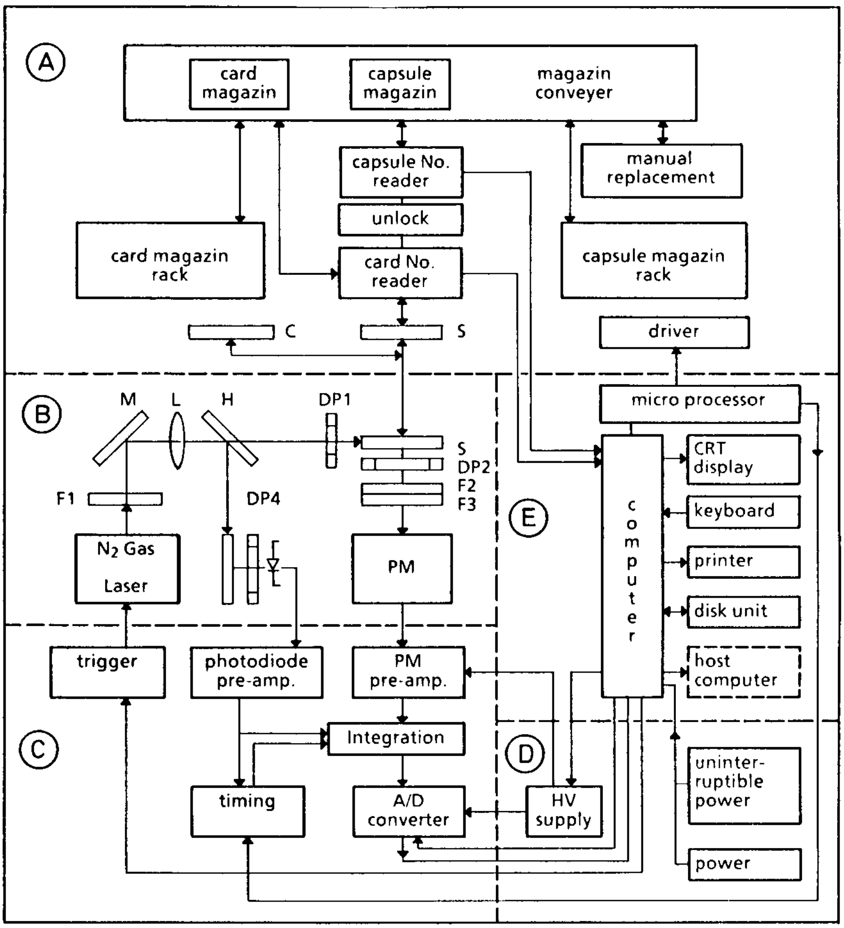


Fig. 3 Energy dependence of the glass dosemeter



M:	mirror	PM:	photomultiplier	F3:	orange filter
L:	lens	D:	photodiode	S:	sample glass
H:	half mirror	F1:	UV pass filter	R:	reference glass
DP:	diaphragm	F2:	UV cut-off filter	C:	calibration glass

Fig. 2 Diagram of the TOSHIBA FGD-10 glass dosimetry read-out system

Tab. 1 Dosimetric Properties of Phosphate glass and TL Dosemeters Using Automatic Readout in the Toshiba FGD-10 and Alnor Dosacus reader

	PLD System (FGD-10)	TLD System (LiF:Mg,Ti)
Dose range	0.03-10 Sv	0.03 - 1 Sv
Batch uniformity		
response	± 2 %	±10 %
pre-dose	(0.03±0.02) mSv	(0.06±0.03) mSv
Random uncertainty (H_{nat} + 50 μSv – 110 μSv)	± 5 %	± 10 %
Energy dependence		
Exposure free in air	25 keV - 1.2 MeV ± 20 %	15 keV - 1.2 MeV ± 20 %
H'(10) on phantom	10 keV - 1.2 MeV ± 10 %	20 keV - 1.2 MeV factor 2[1)]
Fading at 20° C	- 10 %/10 years	-20 %/1 year

1) Without energy compensation filter

CONCLUSION

In conclusion the new automatic dosimetry system for a large-scale application of personnel dosemeters offers the following advanteages:

- The technique of the automatic read-out namely the microprocessor supported evaluation, the reliability of measurement, the read-out time for one dosemeter and the capacity of magazins and data storage as well as the dosimetric properties of the system such as detector sensitivity, lower detection limit and random uncertainty of dose measurement are comparable with those of modern automatic TLD systems.
- The excellent batch uniformity in response and pre-dose, the relatively low energy dependence of dose measurement for the simultaneous indication of different dose quantities and the long-term stability of dose information with respect to repeated read-outs and environmental effects are, however, properties so far not offered by TLD systems.
- Phosphate glass dosemeters are still superior to TLD systems with respect to the simplicity of the read-out procedure, the permanent availability of dose information, in particular the capability to repeat the read-out procedure and to indicate the accumulated dose between daily, monthly and annual read-outs. In the case of accidents high dose values can be measured and the radiation induced effect can be confirmed by an annealing of the reading followed by a recalibration of the actual glass with respect to response and pre-dose.

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