ACOUSTIC SIGNAL GENERATION IN EXCISED MUSCLE BY PULSED PROTON BEAM IRRADIATION AND THE POSSIBILITY OF ITS CLINICAL APPLICATION TO RADIATION THERAPY

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Acoustic signals generated in liquids and in metals by pulsed proton beam have reported by several authors [1][2]. These signals are thought to be thermal shock wave due to localized energy deposition of incident protons. Thus the intensity of generated acoustic signals is almost proportional to the energy deposited at the region. This suggests the possibility for measuring spatial distribution of energy deposition of proton beam using acoustic method.

An energetic proton incident into a homogeneous medium loses energy continuously along the course of penetration. The maximum energy loss of the incident proton occurs at the end of its trajectry as shown in Fig.1. Therefore proton beam can damage matters at the depth of its range almost selectively. In radiation therapy by proton beam, the patient treatment planning is performed based on the data of X-ray computer tomography which reflects the information of electron density distribution in the patient's body. Ensuring the agreement of the dose distribution in the patient with the planned one, however, is difficult. It is sugested that the acoustic method can provide a usefull tool for this perpose.

The pulsed proton beam of 50ns in pulse width is utilized for cancer therapy at Particle Radiation Medical Centre (PARMS), University of Tsukuba. The typical dose distribution curve is shown in Fig.1. The peak dose was approximately 0.05Gy/pulse. A hydrophone (Model ST-8004, Okidenki Co.,Ltd) was utilized for the detection of acoustic signal generated by pulsed proton beam. The sensitivity of the hydrophone was -220dB (0dB=1V/μPa in the frequency range between 0Hz and 300kHz). Detected signals were amplified ten thousand times befor averaged and analysed by digital oscilloscope.

Fig.2a and Fig.2b give examples of acoustic signal generated in water by pulsed proton beam where the intensity of the beam is approximately 0.05Gy/pulse in the peak dose. The proton range is adjusted 4.5cm and 7.5cm in the measurement of Fig.2a and Fig.2b respectively. As shown, acoustic signal generated at the depth where proton dose is maximum reaches approximately 20 μsec earlier in Fig.2b than in Fig.2a. The time difference is corresponding to the time for the acoustic signal traveling 3cm distance in water.

Fig.3 shows an acoustic signal generated by the pulsed proton beam in excised pig muscle supported on water surface. This result suggests the possibility of future clinical application to radiation therapy.

These experiments were performed, however, using about twenty times more intense proton beams than those used in actual proton radiation therapy at PARMS. Therefore it is necessary to assure that acoustic signals generated by proton beams of the clinical intensity can also be detectale. Fig.4 is the answer for this problem. In this case, the peak dose of the proton beam is about 0.0003Gy/pulse and the signal is still recognizable enough.

REFERENCES

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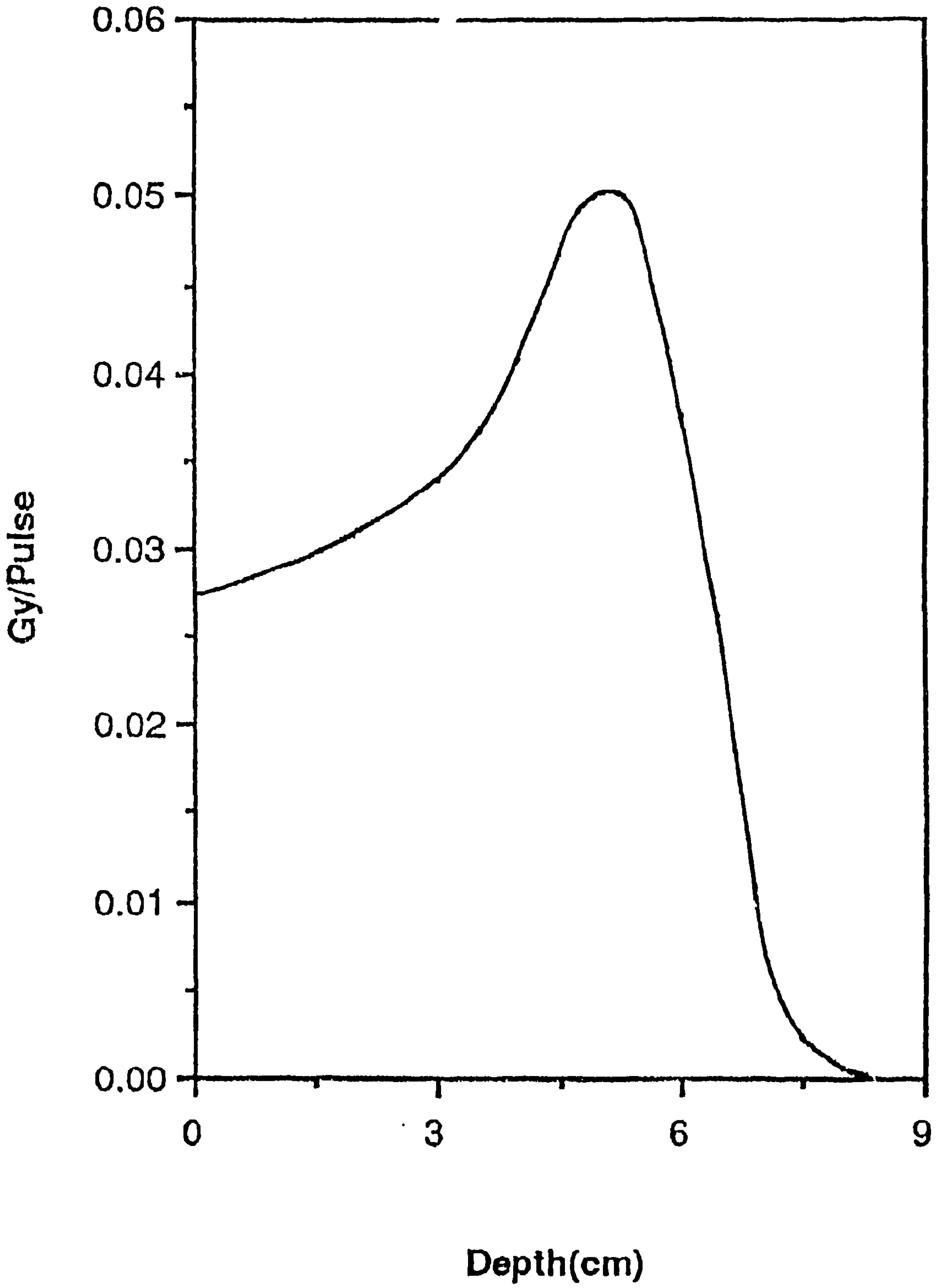


Fig.1

Proton depth dose distribution in water.[3]

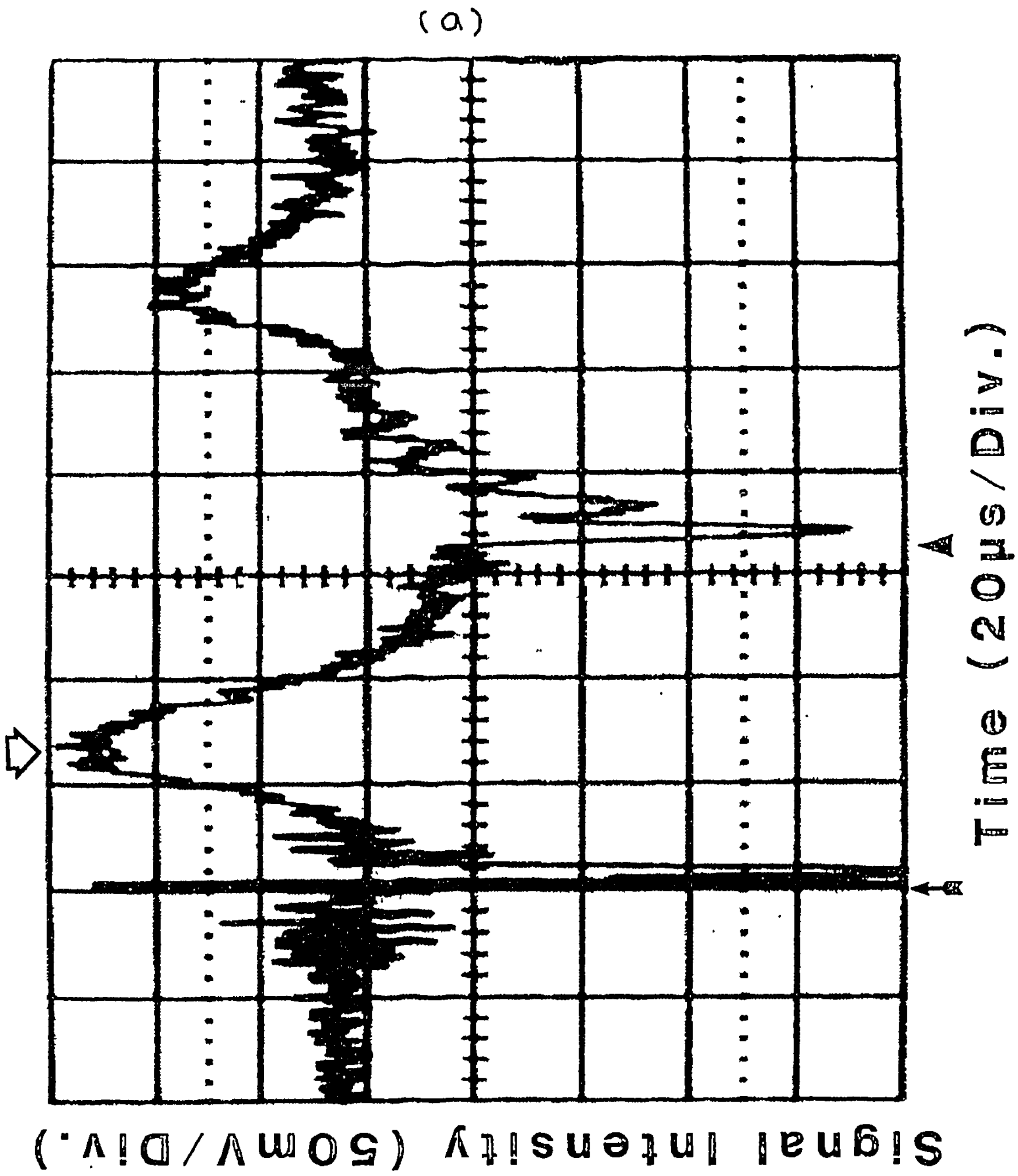
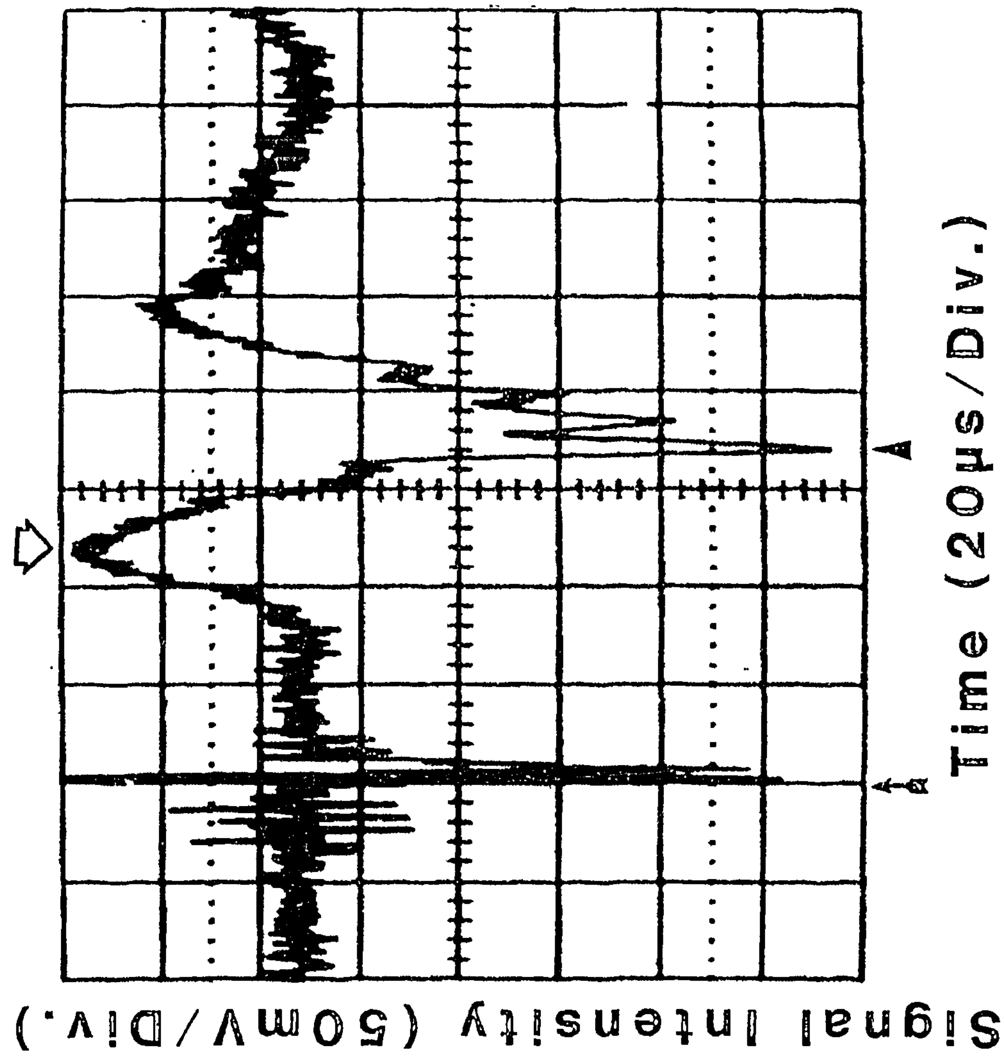


Fig.2

Acoustic signals generated in water by pulsed proton beam. Ordinate scale is 50mV/div. and abscissa scale is 20μ sec/div.. (a)Signal by proton beam with maximum range about 4.5cm in water. (b)Signal by about 7.5cm range proton beam. Closed arrow s indicate the time of proton beam incidence, while open ones at the top indicate signals generated at the depth of peak dose. Steep falls of acoustic pressure, indicated by arrow heads, correspond to water surface.[3]

(b)



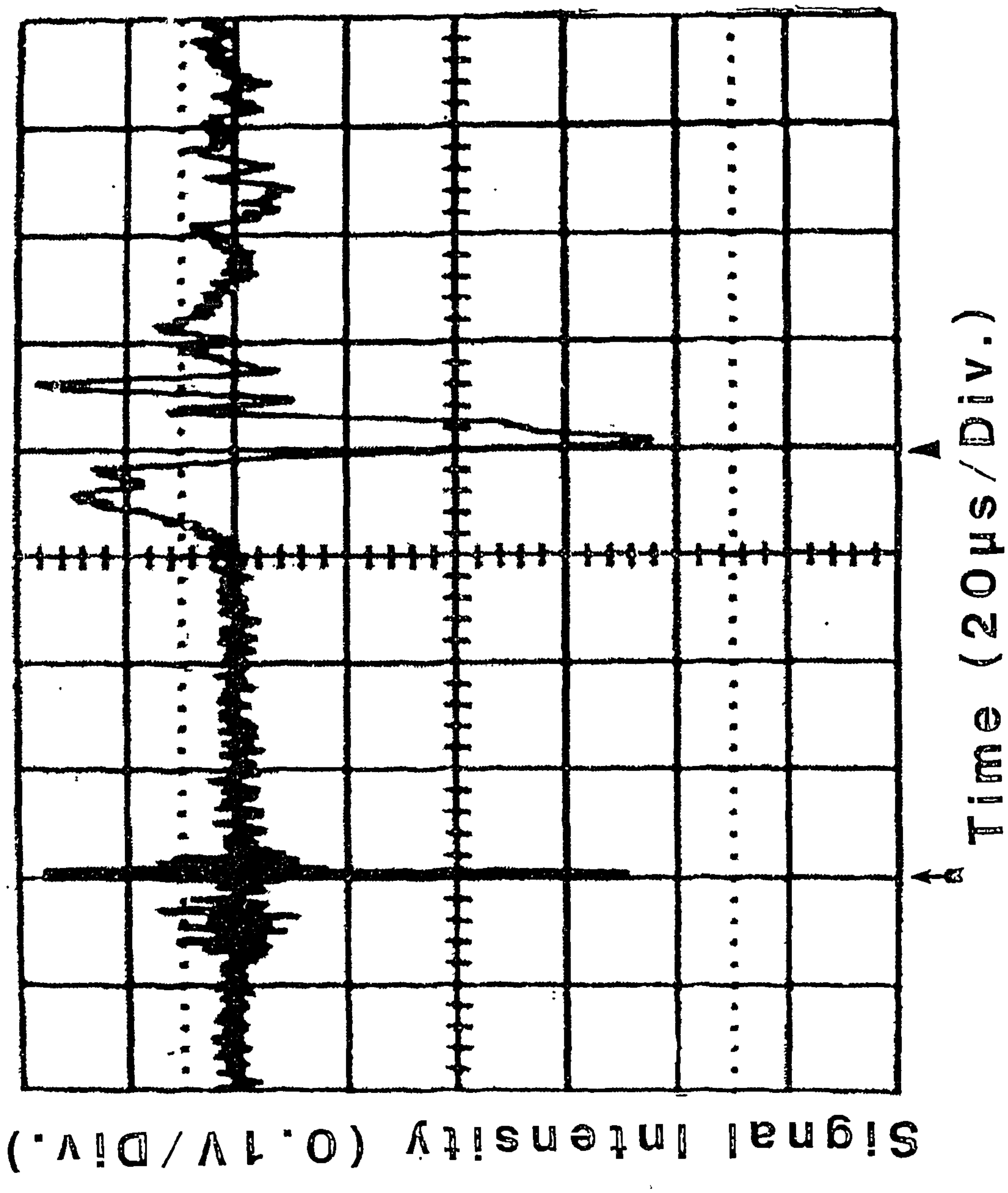


Fig.3

Acoustic signal generated by pulsed proton beam in excised pig muscle of approximately 3cm thick supported on water surface. Range of the proton beam is about 2.5cm.[3]

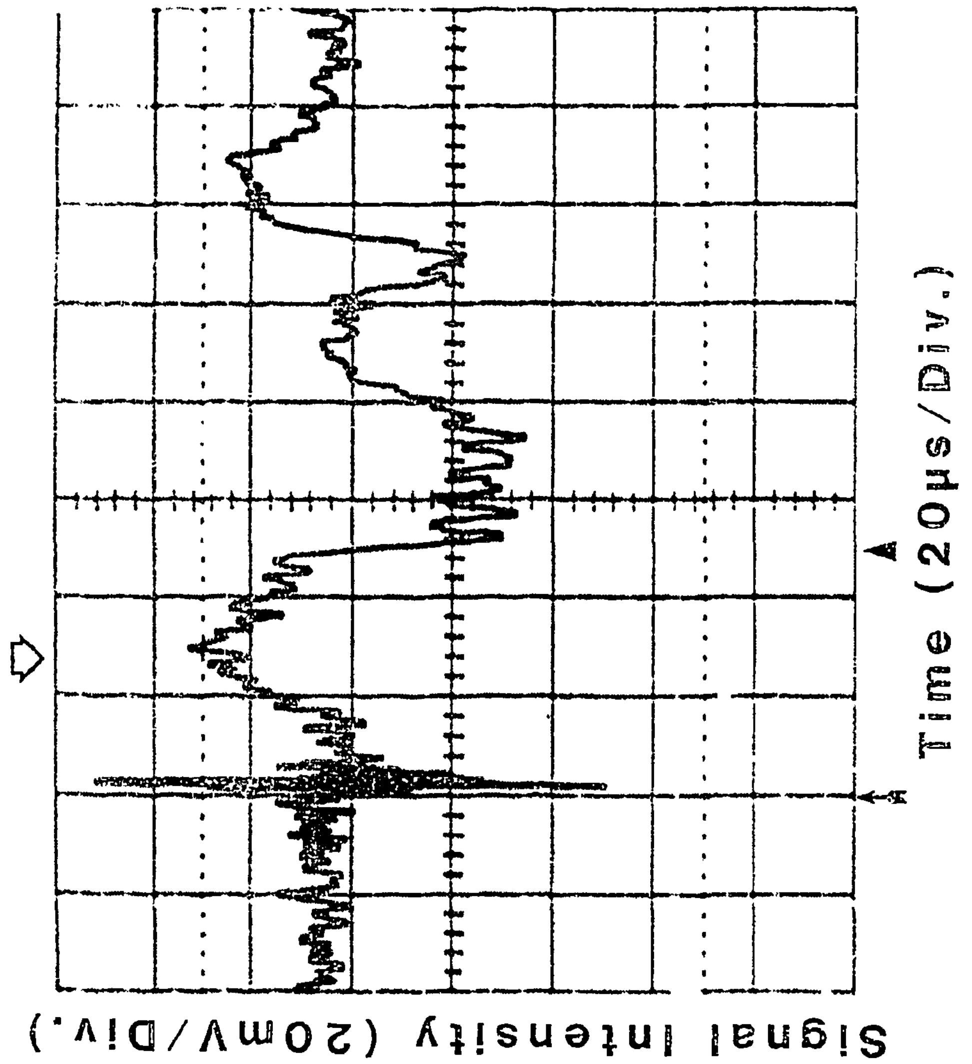


Fig.4

Acoustic signal generated by pulsed proton beam of clinically applied intensity.