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SCANNING X-RAY DIFFERENCE MICROSCOPY AND MICROTOMOGRAPHY USING SYNCHROTRON RADIATION OF THE STORAGE RING VEPP-4

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A device designed to be employed for X-ray transmission difference microscopy and microtomography at the X-ray absorption edges of chemical elements using synchrotron radiation is described. The device comprises a double-crystal monochromator, collimator system, object scanning unit and two X-ray detection blocks based on an NaI(Tl) crystal, photomultiplier (FEU-130) and appropriate electronics. As an example of the practical application of this technique, the first results on the diagnostics of the lymph system by lymphography, i.e. the visualization of the lymph nodes previously contrasted by a Th-containing preparation, are presented. These results have been obtained at the Th L_{III}-edge ($E_\gamma = 16.3$ keV) using difference microscopy and microtomography.

For years X-ray microscopy has been in general use in studies on the spatial structure of microobjects. Substitution of the radiation of X-ray tubes, usually used in this scheme, by the synchrotron radiation (SR) of electron storage rings opens unique additional possibilities for research. First, the high spectral density of SR makes it possible to perform microscopy with monochromatic radiation thereby simplifying the interpretation of the radiographs obtained. Second, the broad spectrum of SR coupled with the ease in the tuning of the radiation wavelength allows an optimal wavelength of the transmission radiation to be chosen and, hence, to minimize the duration of scanning at a given precision of measuring the coefficient of radiation attenuation at each point of the object under study. And, third, these properties make for ease in the realization of difference microscopy at the X-ray absorption edge of a particular chemical element [1].

A schematic view of the device intended for scanning X-ray microscopy using synchrotron radiation from the VEPP-4 storage ring is shown in fig. 1. Having passed through the primary diaphragm, the SR beam arrives at a double-crystal monochromator with Ge(111) crystals. The monochromatic beam then subsequently travels through the vertical and horizontal collimators between which there is a photomultiplier with a NaI(Tl) scintillator [2]. This PM monitors the radiation falling on the object to be studied and operates in the counting regime of the quanta scattered on a light scatterer (Be, acrylic plastic). The latter is placed in the beam between the collimators. After collimation the radiation is incident on the subject under study, which is attached to a

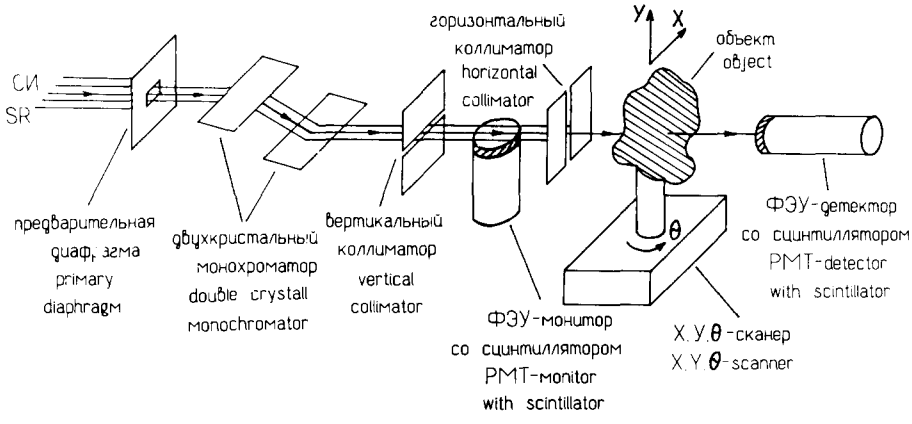

Fig. 1. Layout of the device for scanning X-ray microscopy and microtomography.

two-coordinate scanning unit. This unit, equipped with stepping motors, permits the coordinate to be changed in 0.1 μm steps. For studies in X-ray transmission microtomography [3] the scanner is also capable of varying the projection of observation of an object with a 0.9° step. The radiation quanta transmitted through the object are detected by a PM-detector, similarly to a PM-monitor. The device is computer-controlled on the basis of the CAMAC standard.

In difference microtomography, in order to verify a restoration of the cross section, an acryilc plastic cylinder of 10 mm diameter has been utilized as a test sample. This cylinder has four axial 1.5 mm-diameter channels filled with solutions of 10% and 5% Th and 5% and 2.5% I, separately.

The human lymph nodes were the first objects of research using the device under discussion. An attempt was made to examine experimentally the lymph system in case of inflammation or tumours.

Figs. 2a and 2b show the usual and difference radiographs of a normal human lymph node, which have been taken at 100×100 points at the Th L_{III}-edge

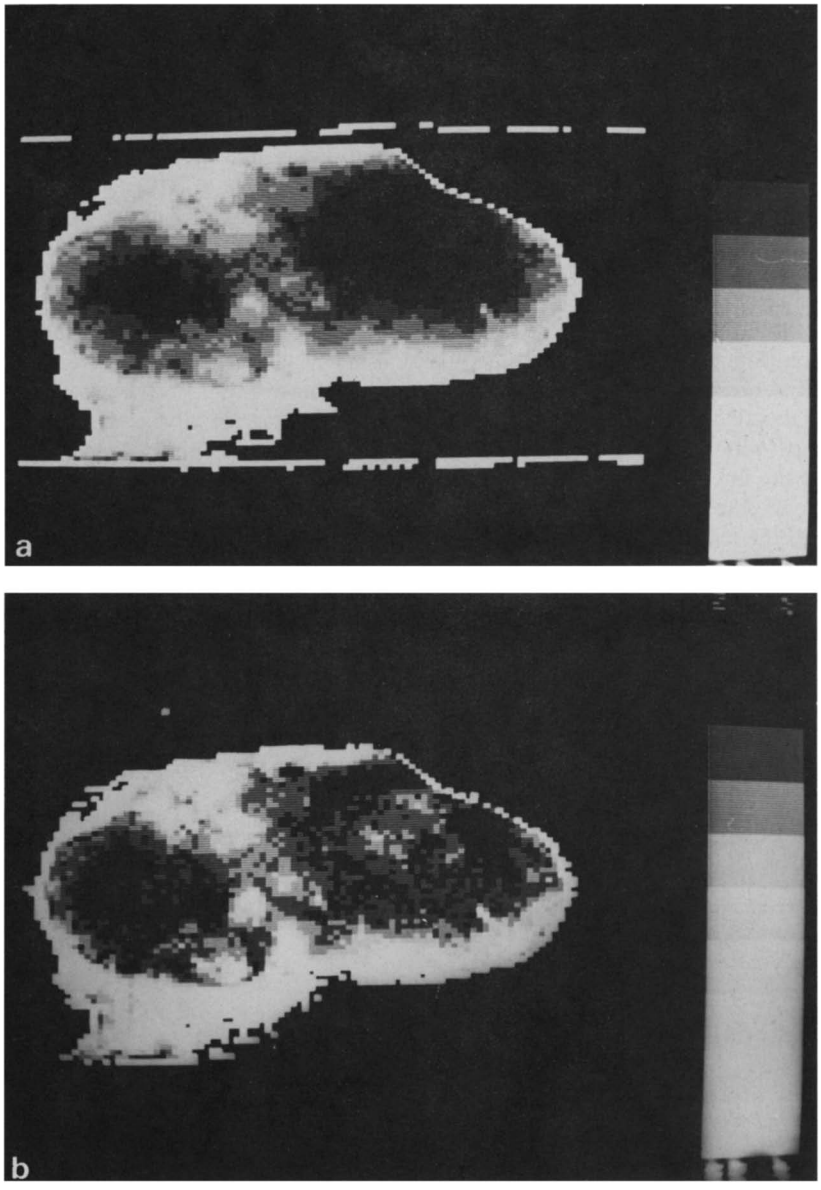

Fig. 2. (a) Usual and (b) difference radiographs of a normal human lymph node.

($E_\gamma = 16.3$ keV). The cross section of the transmission radiation beam was 65×65 μm. The scanning step over both coordinates was 100 μm. Figs. 3a and 3b demonstrate the usual and difference radiographs of a pathological lymph node, which have been taken under the same conditions. In figs. 4a and 4b one can see the usual and difference tomographs of a cross section of the test sample. Figs. 5a and 5b show the usual and difference radiographs of the lymph node whose cross section A is presented in figs. 6a and 6b by the usual and difference tomographs, respectively.

The experimental data obtained confirm that in going to the utilization of synchrotron radiation the lymphography methods permitting the visualization of the previously contrasted blood vessels and lymph nodes by means of X-ray radiation, can be developed at a qualitatively new level. A scanning difference radiograph or tomograph with a resolution ranging from 10 to 100

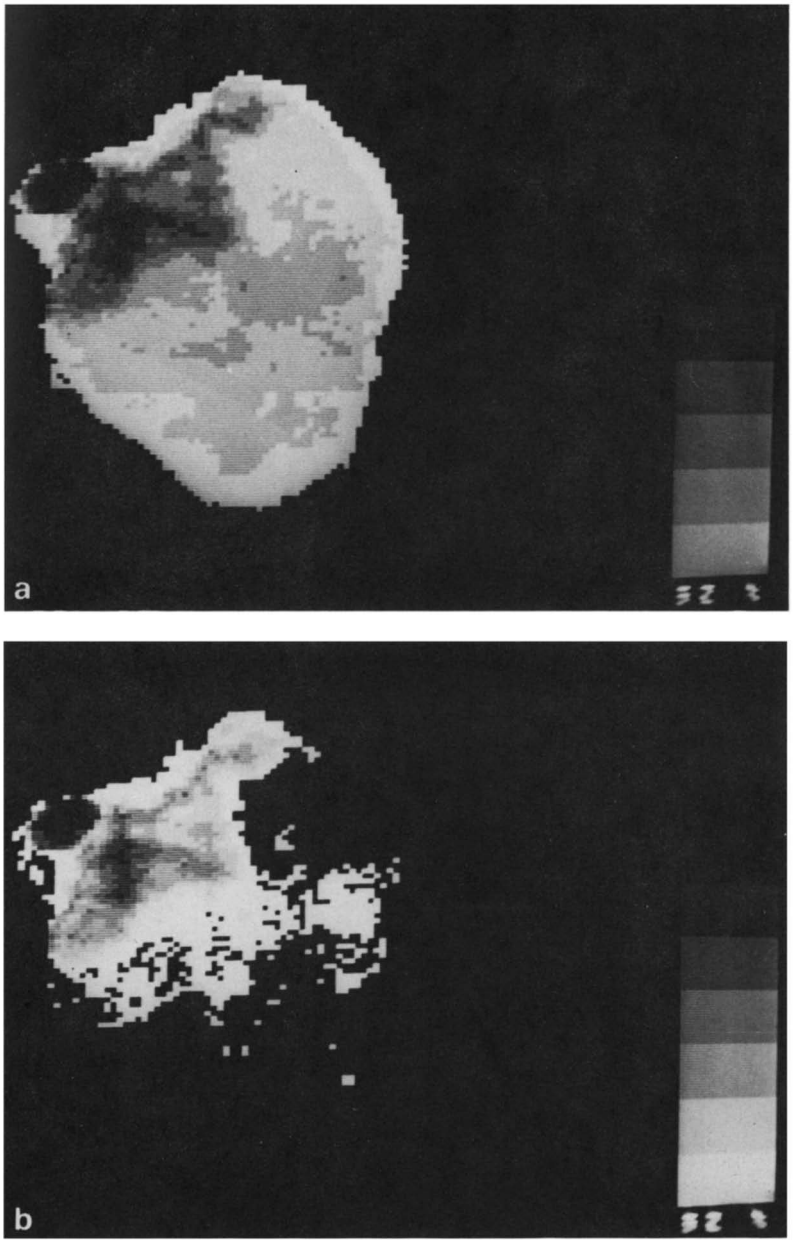

Fig. 3. (a) Usual and (b) difference radiographs of a pathological human lymph node.

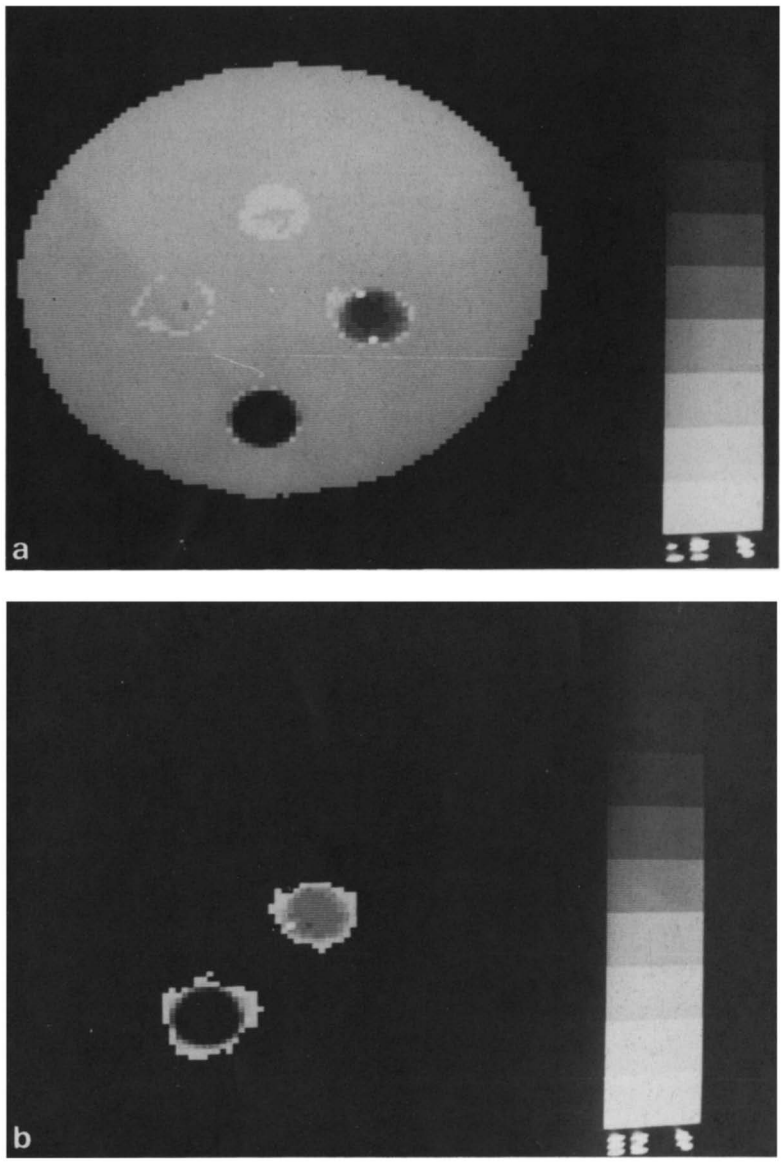

Fig. 4. (a) Usual and (b) difference tomographs of a cross section of the test sample.

μm, which is obtained at the K or L X-ray absorption edges of the chemical elements previously introduced in the composition of the contrast preparations at relatively low concentrations, enables one to reveal the distribution of the preparation at macro- and micro-levels. This makes it possible to study the distribution mechanisms, opens the prospects of investigating the lymphatic system experimentally and, possibly, in clinical practice.

At present studies are in progress which are aimed at increasing the transmission radiation intensity with the help of a focusing monochromator (this will alow the cross section of the monochromatic beam to be reduced) and at improving the spatial resolution of radiographs. The utilization of a one-coordinate detector with high spatial resolution, (for example, CCD-structure detectors [4]), will accelerate considerably the process of exposure of the radio- and tomographs.

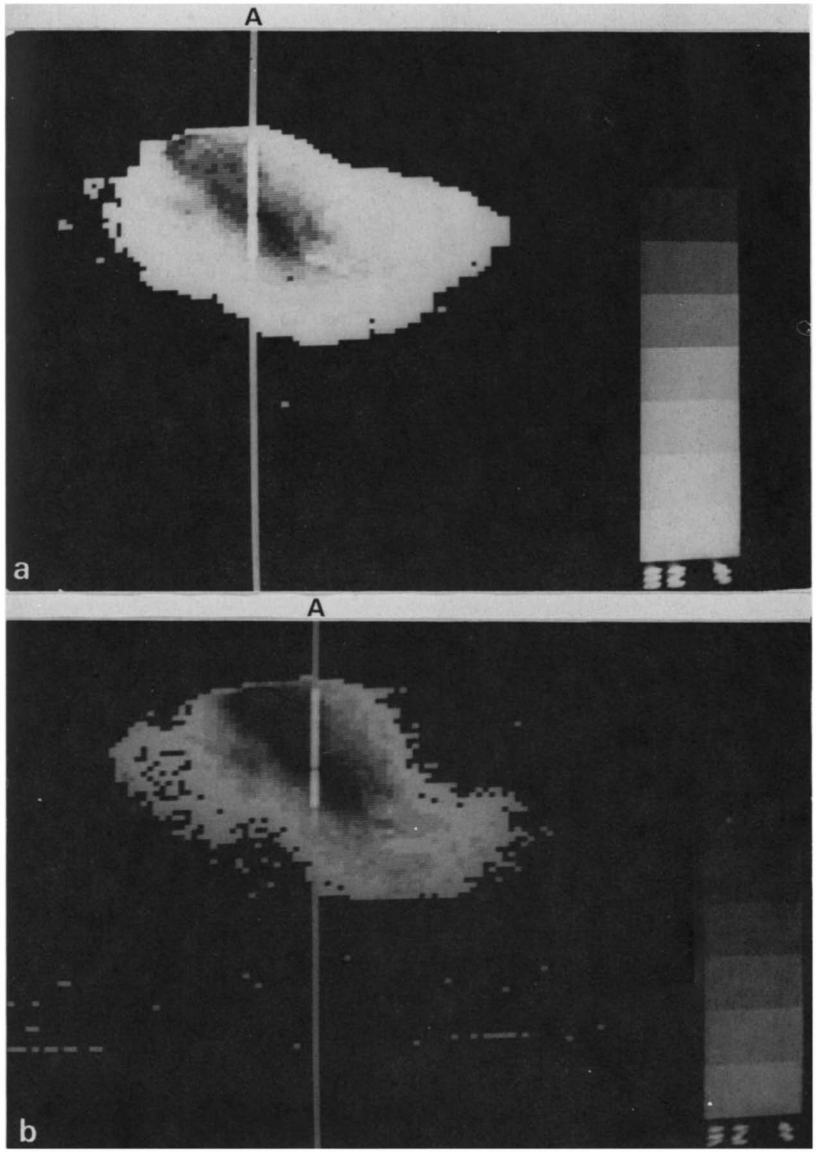

Fig. 5. (a) Usual and (b) difference radiographs of a lymph node with section A for microtomography.

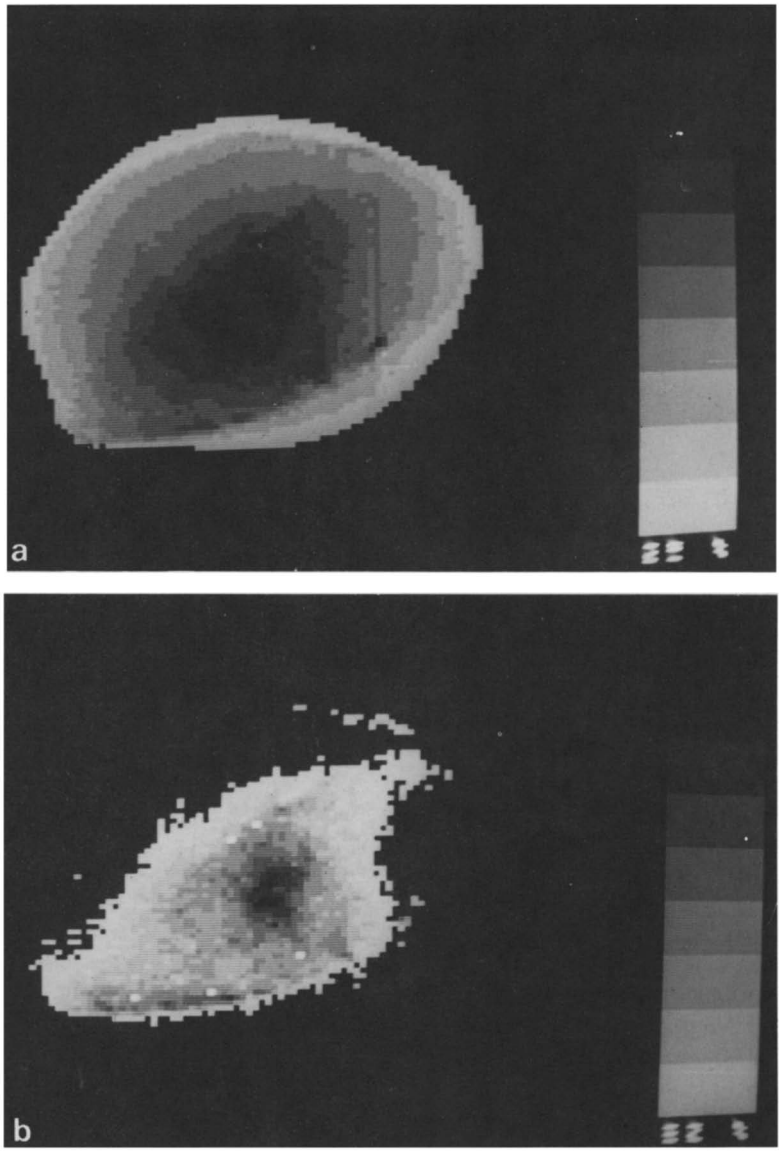

Fig. 6. (a) Usual and (b) difference tomographs of cross section A of the lymph node in fig. 5.

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