$$\cos\beta=\frac{u_1u_2+v_1v_2+t_1t_2+\frac{1}{2}(u_1v_2+u_2v_1+u_1t_2+u_2t_1+v_1t_2+v_2t_1)+\frac{1}{3}w_1w_2(c/a)^2}{[u_1^2+v_1^2+t_1^2+u_1v_1+u_1t_1+v_1t_1+\frac{1}{3}w_1^2(c/a)^2]^{1/2}[u_2^2+v_2^2+t_2^2+u_2v_2+u_2t_2+v_2t_2+\frac{1}{3}w_2^2(c/a)^2]^{1/2}}\,.$$

Pertinent references for this Appendix are Govila (1969), Lawley (1960), Metzbower (1969), Nicholas (1966, 1970), Salkovitz (1951), Taylor & Leber (1954).

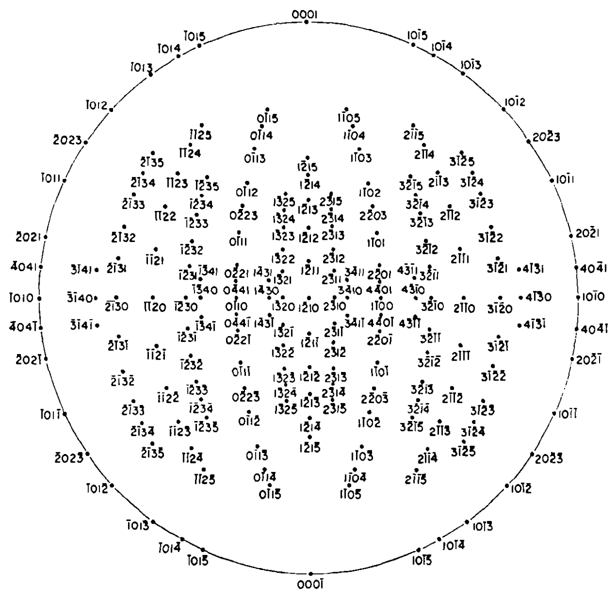

Fig. 15. (1$\bar{2}$10) standard projection for zinc $(c/a)=1{\cdot}8563$).

References

ANDRADE, E. N. DA C. & RANDALL, R. F. Y. (1950). *Proc. Phys. Soc.* **B63**, 198.

ARNSTEIN, G. M. (1970). M.Sc. Thesis, Univ. of Maryland.

BLAKELY, J. M. & MYKURA, H. (1966). *Acta Metall.* **9**, 595

DARKEN, L. S. & GURRY, R. W. (1953). *Physical Chemistry of Metals*, p. 349. New York: McGraw-Hill.

DRECHSLER, M. & NICHOLAS, J. F. (1967). *J. Phys. Chem. Solids*, **28**, 2609.

GIBBS, J. W. (1961). *The Scientific Papers of J. Willard Gibbs*, Vol. 1 (*Thermodynamics*), p. 55. New York: Dover.

GJOSTEIN, N. A. (1963). *Acta Metall.* **11**, 969.

GOVILA, R. K. (1969). *TMS Paper Selection*, No. A69–12. The Metallurgical Society of AIME.

HERRING, C. (1951). *Phys. Rev.* **82**, 87.

KIRCHNER, H. O. K. & CHADWICK, G. A. (1969). *Phil. Mag.* **20**, 406.

LAWLEY, A. (1960). *Trans. TMS-AIME*, **218**, 957.

METZBOWER, E. A. (1969). NRL Report 6919, Naval Research Laboratory, Washington, D.C.

MILLER, W. A., CARPENTER, G. J. C. & CHADWICK, G. A. (1969). *Phil. Mag.* **20**, 406.

MOORE, A. J. W. (1958). *Acta Metall.* **6**, 293.

MOORE, A. J. W. (1963). *Metal Surfaces: Structure, Energetics and Kinetics*, p. 155. Cleveland: ASM.

MYKURA, H. (1969). *Molecular Processes on Solid Surfaces*, p. 129. New York: McGraw-Hill.

NICHOLAS, J. F. (1965). *An Atlas of Models of Crystal Surfaces*. New York: Gordon and Breach.

NICHOLAS, J. F. (1966). *Acta Cryst.* **21**, 880.

NICHOLAS, J. F. (1970). *Phys. Stat. Sol.* (*a*) **1**, 563.

SALKOVITZ, E. I. (1951). *Trans. TMS-AIME*, **191**, 64.

SCHULTZ, J. M. & ARMSTRONG, R. W. (1964). *Phil. Mag.* **10**, 497.

TAYLOR, A. & LEBER, S. (1954). *Trans. TMS-AIME*, **200**, 190.

WOLFF, G. A. & GUALTIERI, J. G. (1962). *Amer. Miner.* **47**, 562.

WULFF, G. (1901). *Z. Kristallogr.* **34**, 449.

Acta Cryst. (1972). A**28**, 353

On a New Retigraph with Pure Precession Motion

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A new precession retigraph is described which allows precession angles of up to 45°. It does not contain a universal-joint suspension, and it has a pure precession motion.

Introduction

An instrument capable of giving an undistorted photograph of the reciprocal lattice is usually called a 'retigraph'. All retigraphs are characterized by the presence of a crystal support and a film support, both of which must have exactly the same movement. One can identify three classes of instruments depending on the kind of movement: rotation models, precession models and generalized-movement models. The retigraphs of the different classes give spots of different shapes, and different Lorentz factors must be used in correcting the intensities.

The first retigraph was built by de Jong & Bouman

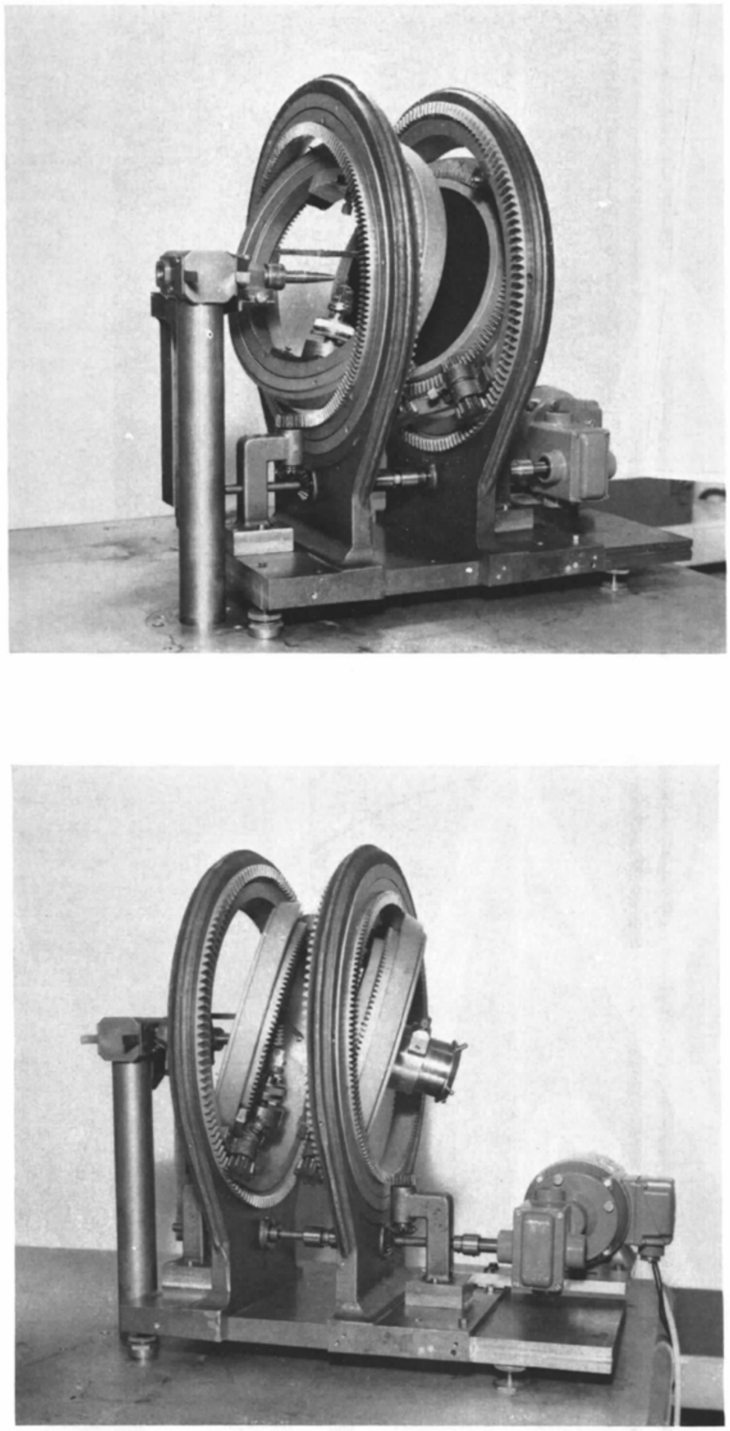


Fig. 1. Two general views of the instrument; the layer-line screen was removed.

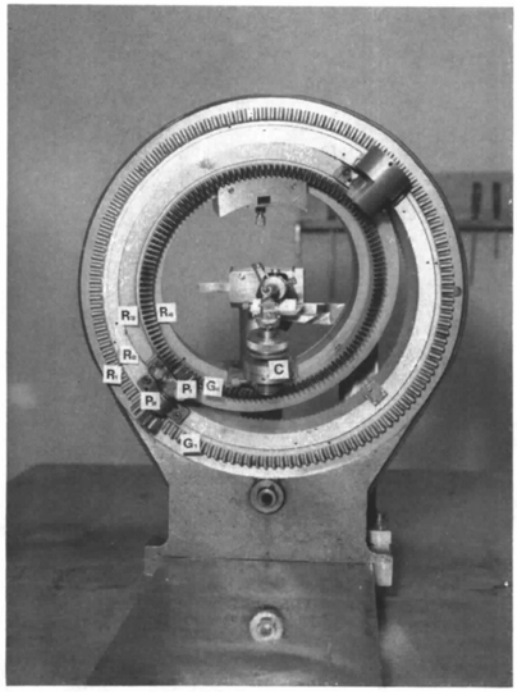


Fig. 2. Front view of the crystal stand, the layer-line screen being removed. For explanations see text.

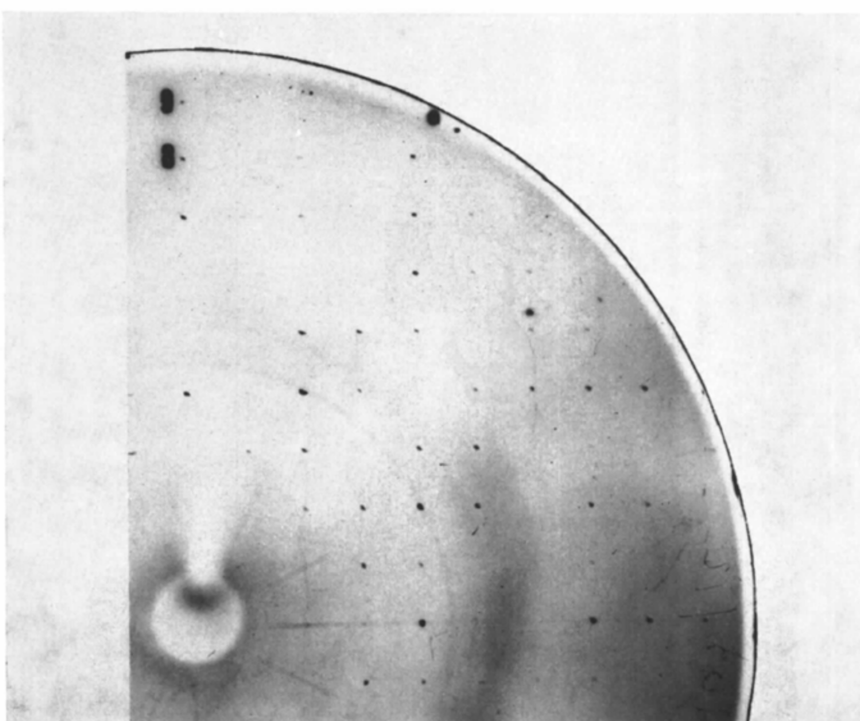
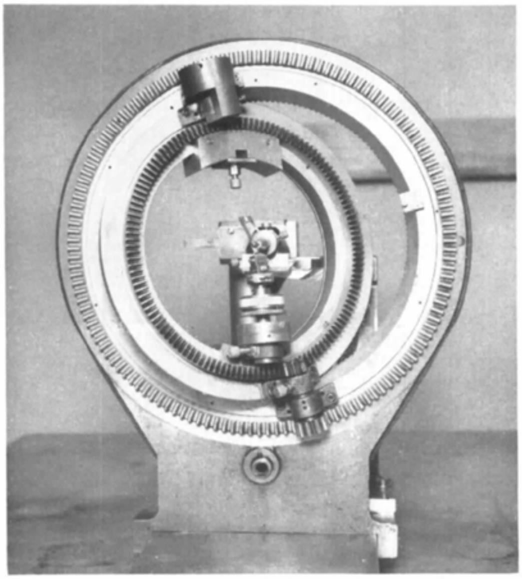
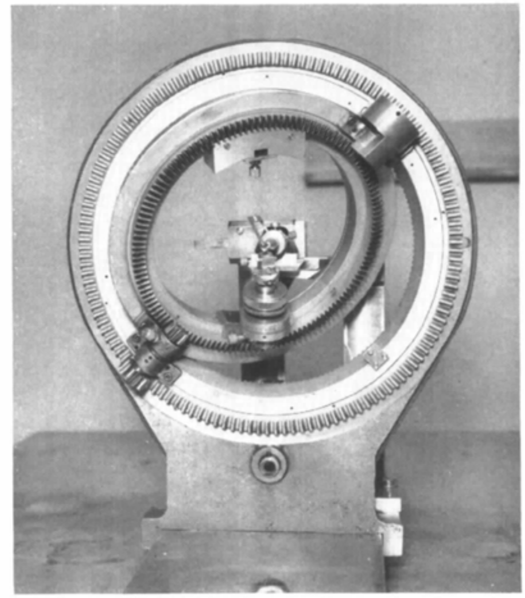


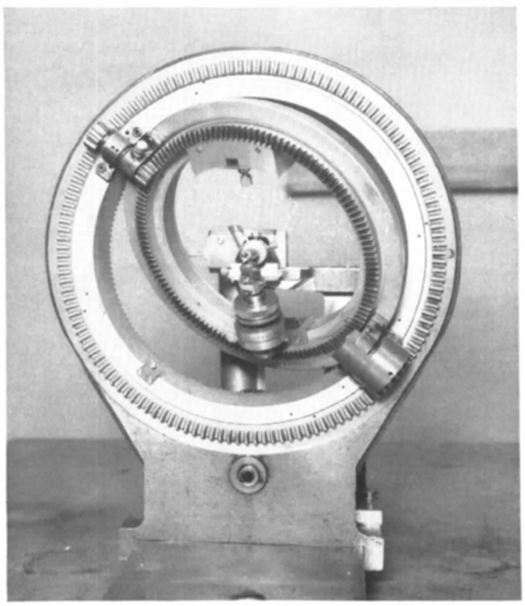
Fig. 3. Photograph (Ni-filtered Cu radiation) of the *hk*0 layer of the reciprocal lattice of vesuvianite (tetragonal with $a=$ 15·66 Å) taken with this instrument at $\mu=40°$. Numbers 8 and 9 mark diffractions (880) and (990) which would not be taken at $\mu=30°$.



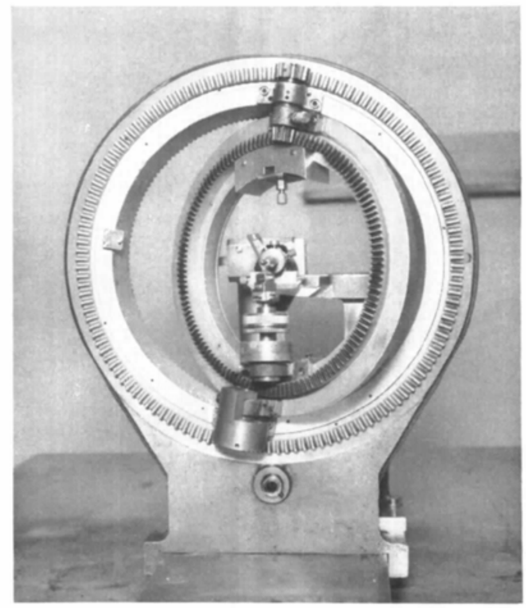
(a)



(b)



(c)



(d)

Fig. 4. Four successive views of the crystal stand, presented so as to give an idea of how the precession motion is achieved.

(1938), and it was of the rotation type. Subsequent models of rotation retigraphs were built by Rimsky (1952), Wooster (1955) and others.

The first precession retigraph was built by Buerger (1944). Waser (1951) showed the motion of Buerger's instrument to be nearly, but not exactly, a precession. Corni & Gottardi (1964) modified Buerger's instrument so as to obtain photographs with intensities equal to those given by a precession retigraph. Buerger (1963) designed another model of a retigraph with pure precession motion.

This paper presents the description of an entirely new retigraph with pure precession motion, allowing precession angles up to 45°, a value never before reached.

Description of the instrument

A whole view of the instrument is shown in Fig. 1. The main part of the instrument is the crystal stand (see Fig. 2), the film stand obviously being similar.

The crystal is set on a goniometer head which is shorter than usual, the distance between base and crystal being 45 mm. The small head Stoe (model 0.12.1) is particularly suitable. The goniometer head can be adjusted for height with a screw (not visible in Fig. 2); the head can be rotated and its position is read on circle **C**; this circle is fixed when taking a photograph.

The goniometer head and the circle **C** are set on **R**4, the innermost of four rings coded **R**1, **R**2, **R**3, **R**4. The ring **R**1 is fixed; rings **R**1 and **R**2 stay in the same plane; **R**2 is rotatable on **R**1 by means of a ball race 'Kaydon Reali–Slim *KC* 100 *CP*'. Rings **R**3 and **R**4 are also rotatable on the same plane, a ball bearing '*KC* 70 *CP*' made by the same firm being inserted within. The angle between the rings **R**2 and **R**3 can be adjusted between 0 and 45° and is equal to the precession angle μ. The axis around which ring **R**3 is tilted with respect to ring **R**2 bears two pinions **P**1 and **P**2 with the same number of teeth. These two pinions 'climb' on two gears **G**1 and **G**4, which again have the same number of teeth: **G**1 is part of **R**1, **G**4 is part of **R**4. Another gear, **G**2, is part of **R**2, but cannot be seen in Fig. 2 as it is on the other side of the stand. The crystal stand is driven by an electric motor through a pinion which rotates gear **G**2 and hence ring **R**2. As ring **R**2 rotates, pinions **P**1 and **P**2 'climb' on **G**4 and **G**1 so that ring **R**4, and hence the goniometer head, perform a precession motion.

Fig. 3 shows a precession photograph (Ni-filtered Cu radiation) of the *hk*0 layer of the reciprocal lattice of vesuvianite (tetragonal with $a = 15{\cdot}66$ Å) taken with this instrument at $\mu = 40°$. Here the diffractions 880 and 990, which are out of reach at $\mu = 30°$, can be seen The photograph is marred by some shadows, owing to the still imperfect setting of the instrument. The series of four pictures in Fig. 4 gives an idea of how the crystal stand works.

Reasons for building the instrument

The decision to build a new retigraph was made when I was having trouble taking photographs with very tiny crystals; for these crystals copper radiation is the only one suitable, and even then the photographs were very faint. It was thus advisable to take undistorted pictures of the reciprocal lattice in order to make their interpretation easier. With copper radiation and a conventional precession retigraph the number of observable diffractions was small: to obtain more diffractions an increase in μ was necessary.

That was the starting point. Whether the instrument will perform successfully in these special cases, *e.g.* in the case of very small crystals, is not yet certain. Naturally, the machine is not without its teething troubles, and proposed modifications and improvements are now being tested.

I thank F. Bagni who is responsible for the actual design of the instrument and for the solution of many technical problems. R. Ansaloni built most parts in the Institute workshop. Thanks are due to the firm Colleoni, Milan, representatives for Italy of 'Kaydon, Muskegon, Mich.', for some useful suggestions. This research was made possible through the financial support of the Consiglio Nazionale delle Ricerche, Roma.

References

Buerger, M. J. (1944). *AXSRED Monograph No.* 1.
Buerger, M. J. (1963). U.S. Patent No. 3108185.
Corni, V. & Gottardi, G. (1964). *Rev. Sci. Instrum.* **35**, 1613.
Jong, W. F. de & Bouman, J. (1938). *Z. Kristallogr.* (*A*), **98**, 456.
Rimsky, A. (1952). *Bull. Soc. Franç. Miner. Crist.* **75**, 500.
Waser, J. (1951). *Rev. Sci. Instrum.* **22**, 563.
Wooster, W. A. (1955). *Acta Tech. Acad. Sci. Hung.* **12**, 165.