The magnification changer in optical microscopy and its unusual and lesser known precursor, ie the Revolver ... of the eyepieces (!)

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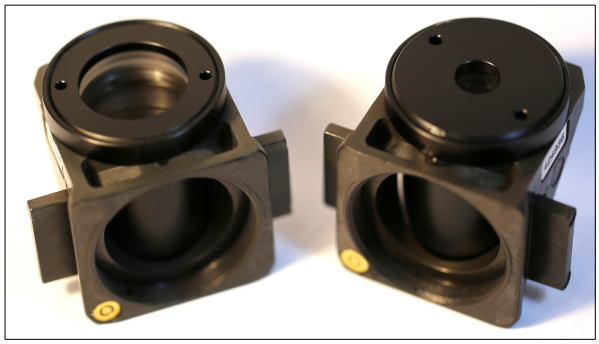
The magnification changer is an accessory that is precisely inserted into the optical path of the microscope and between the objectives and the eyepieces. Almost all the major manufacturers of microscopes have it in their catalogues, but not everyone has heard of or actually know its strengths and its technical limits; limits that to tell the truth are few compared to the advantages it offers. Not surprisingly, its precursors already existed in the first half of the twentieth century.

As for the Zeiss brand, the magnification changer had a strong lineage starting from 1954, when it was introduced as part of a further accessory called the Optovar, initially conceived for the model W. Today the terms magnification changer and Optovar are often considered synonyms. However, in the model W manual (1) [bracketed numbers refer to the Bibliographic Notes at the end of this publication] the Optovar is already described as a device in turn made up of other components, ie not only the magnification changer, but in this case also an Amici-Bertrand lens (useful for centering phase rings in phase-contrast microscopy) and the analyzer. In the same manual it is specified that the magnification changer is able to increase the magnification choosing between three different factors, ie 1x, 1.6x and 2.5x. In a nutshell the magnification changer is nothing else but an additional lens system designed to vary the magnification of the microscopic image according to a predefined factor. The Optovar was also successfully repeated in the later Universal, Photomicroscope and Ultraphot models, sometimes introducing new magnification factors (1.25x and 2x) and eliminating others.

Photo 1) The author in a small corner of the Diatom Lab. The modern Zeiss Axio Imager.A2 (in the foreground) and Zeiss Axio Scope.A1 (in the background) both for transmitted and reflected light are available. They are both supplied with Optovar Modules P & C placed inside the Reflector Turret for P & C modules.

Today the Zeiss top research microscope, the Axio Imager.A2 (currently in use at Diatom Lab and therefore well known to the author) has two possibilities to vary the magnification in this sense: either by inserting one or more “Optovar modules P & C” (only for transmitted light) 1.25x, 1.6x and 2.5x into the “Reflector turret for P & C modules” (6 or 10 positions), or by inserting one or more "Tube lenses" (1.25x, 1.6x, 2.5x and 4.0x) into the "5-position tube lens turret with Bertrand system".



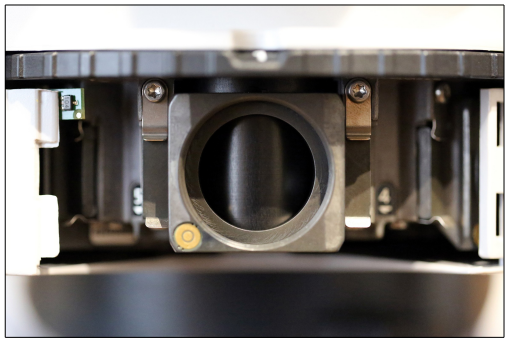


Photo 2) Left. Two of the Optovar P & C Modules for Zeiss Axio Imager.A2 and Zeiss Axio Scope.A1 used in the Diatom Lab: 1.25x and 2.5x.

Photo 3) Right. Detail of the Zeiss Axio Imager.A2 research microscope: the 6-position Reflector turret for P & C modules was deprived of its lid to show an Optovar P & C Module perfectly inserted. The Light Manager function of Zeiss Axio Imager allows, if activated, to permanently maintain the intensity of the light depending on the position of the nosepiece and in the motorized models also depending on the position of the Reflector turret and of the Tube Lens Turret.

But why was it (and still is) desirable to equip the microscope with one or more magnification changers, when to increase the latter is enough to turn the objective turret? Here is a detailed list of the undisputed advantages offered by this important accessory:

a) the variation of magnification by means of the magnification changer does not entail any problems of refocusing with either the coarse or fine focus, which occurs when the objectives are not perfectly parafocal. In addition, less experienced microscopists may eventually avoid using oil-based lenses or in any case with reduced working distance, preventing any possible damage to objectives and / or preparations;
b) before changing the objective (for example, changing from a 10x to a 40x) it may be useful to perform small and comfortable intermediate variations of magnification with the magnification changer;
c) in photomicrography it is never good to crop out a digital image to enlarge the photographed object as it can then appear grainy: some enlargement factors of the magnification changers can help you find intermediate magnification solutions between one lens and another (for example, in some cases with a 10x objective the object may be too small in photos, but with a 20x or 40x objective the same object can go beyond the edges of the image);
d) avoids changing / acquiring eyepieces with different magnifications;
e) the magnification changer is very useful when there are problems related to the working distance of the lens; if the thickness of the object to be examined does not allow the user to get close enough for the complete focus, you can use this accessory together with a lower magnification objective. For example, if you

want to enlarge 40 times but the thickness of the object does not allow you to use a 40x objective on all focal planes, it is sufficient to use for example a 20x objective, coupling it to a magnification changer with 2x factor (20x objectives have a working distance generally below 40x objectives).

But the magnification changer also has some technical limitations that it is good to know; if it is true that the image is enlarged, unfortunately it does not actually increase the information that the same provides, and therefore does not increase the resolution! For example, in order to observe more details in this sense, a 40x / 0.75 lens is undoubtedly better than the 20x / 0.50 + magnification changer combination 2x: in fact in this specific case the 40x objective has a numerical aperture of 0.75, while the numerical aperture of the 20x objective is smaller and is not increased by the magnification changer. Moreover, with or without the latter, normally a magnification of 1000 times the numerical aperture of the objective does not provide additional information in the microscopic image, but it generally makes it blurred. In fact, the rule of useful enlargement provides that optimum magnification of an optical microscope is between 500 and 1000 times the numerical aperture of the selected objective (moreover, not everyone knows that in order to make the most of the numerical aperture of the oil microscope objectives, it is necessary to use immersion condensers).

Going back in the history of microscopy, actually the first device with a function of a magnifier was not the Optovar, but the Revolver of the oculars(!). The term "revolver" is well known when it is associated with the microscope objective holder, but few know that in the past there was also a revolving eyepiece (therefore revolving) on which were mounted more eyepieces having a different magnification! Diatom Lab within its collection of vintage microscopes (which are often brought to science fairs to show the preparations containing micromanipulated diatoms and radiolaria made by the author, including several resolution tests) includes an entirely original LwdE , produced by Carl Zeiss Jena, manufactured in 1941 (at that time it belonged to the Tropenmedizinisches Institut of Berlin) and provided just an almost unavailable Revolver of the eyepieces (in German Okularrevolver). This tool, shown in the photos and coming up to us in excellent aesthetic, optical and mechanical condition (despite being less than eighty years old), simultaneously mounts four Carl Zeiss Jena compensating eyepieces (5x, 7x, 10x, 15x) thanks to the Revolver of the eyepieces precisely, as well as four Apochromatic objectives Carl Zeiss Jena (10x / 0.30, 20x / 0.65, 40x / 0.95 with correction ring, 90x / 1.30) and an always original Aplanatic condenser (having numerical aperture of 1.4 and opening diaphragm can be shifted for possible oblique lighting). By simply rotating the Revolver of the eyepieces, the eyepiece placed in front of the observer is changed, and with it the magnification too! For example, only with the 10x objective you can obtain the following magnification combinations: 50x, 70x, 100x, 150x, simply by rotating this handy ocular revolver! The Diatom Test Slide Version 2.0 produced and marketed by Diatom Lab was used to test the LwdE microscope in question and among all the objectives provided stood out in particular the Carl Zeiss Jena 40x / 0.95 with correction ring, which gave excellent results on the first two tests of diatoms, or *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg and *Gyrosigma attenuatum* (Kützing) Rabenhorst (see the attached image, performed with a photographic adapter built *ad hoc* and in oblique illumination obtained by

the decentrable aperture diaphragm present in this microscope).

Photo 4) Left. LwdE Microscope by Carl Zeiss Jena, manufactured in 1941. It is part of the collection of vintage microscopes in Diatom Lab. The eyepiece Revolver is clearly visible.

Photo 5) Right. The same LwdE microscope viewed from the back.

Actually the eyepiece Revolver had appeared in Carl Zeiss Jena microscopes before 1941, in fact according to Carl Zeiss Archives, for example, it was already available in 1933 for the stands LCG, HCE and ESA, in 1935 for the stand LGSA, in 1938 for the stands LgOB, LWdG and LuWdG. Furthermore, it is for example published in the following Carl Zeiss Jena catalogs (please always refer to the Bibliographic Notes present at the end of this publication):

(2) in which the image of the Std LwdG with the Revolver of the eyepieces appears triumphal on the cover; on the inside pages of the catalog this accessory (article 121271) is also mounted on the LuWdG Universal stand and on the Lg OG stand, while a version with visibly shorter eyepiece tubes (item 121275) appears alongside the EOE stand;
(3) Page 4: "Modern Research Microscope with quadruple eyepiece revolver: Stand LwdG" and Page 25: "Quadruple eye-piece revolver without eyepiece";
(4) Page 7, fig. h, art. 121271: "Okularrevolver mit vier schrägstehenden okularstutzen";
(5) Page 4, fig. 10, art. 121271: "Eyepiece revolver with four inclined eyepieces sleeves";
(6) Page 27: "Okularrevolver 4 fach ohne Okulare".

Returning to the model LwdE present in Diatom Lab, it is right to clarify that despite its years it's an instrument of a certain technical sophistication, both for the mechanics, both for the presence of the Aplanatic condenser (with NA 1.4 and decentrable diaphragm) and apochromatic objectives. Recalling the definition of Abbe, Carlo Koristka stated that "the objective (and, in general, the optical system) is apochromatic when it is simultaneously without secondary spectrum and also aplanatic for at least three colors of the spectrum". Compensator eyepieces are practically necessary since they "have been designed to compensate for the chromatic difference in the enlargement presented by those special microscope lenses that are apochromatic and semi-apochromatic" (7). To his father, Francesco Koristka (1851-1933), optician and Italian entrepreneur founder of the company Fratelli Koristka SA (officially opened in 1881), the paternity of semi-apochromatic objectives is recognized (8), which proved that "it was possible, with a suitable combination of glasses (including Fluorite and one of the new special glasses from Abbe and Schott) and with the double advantage of fewer lenses that make up the system (less light absorption and lower manufacturing costs), reach the reduction of the secondary spectrum up to the limits perceivable by the human eye. In this way the microscope objective has all the visual characteristics of apochromatism and can achieve an optical efficiency close to that of the apochromatic objectives, as it requires to be used with compensating eyepieces to eliminate the chromatic difference of the enlargement that, also like apochromatic, is equal in all areas and therefore compensable "(7).

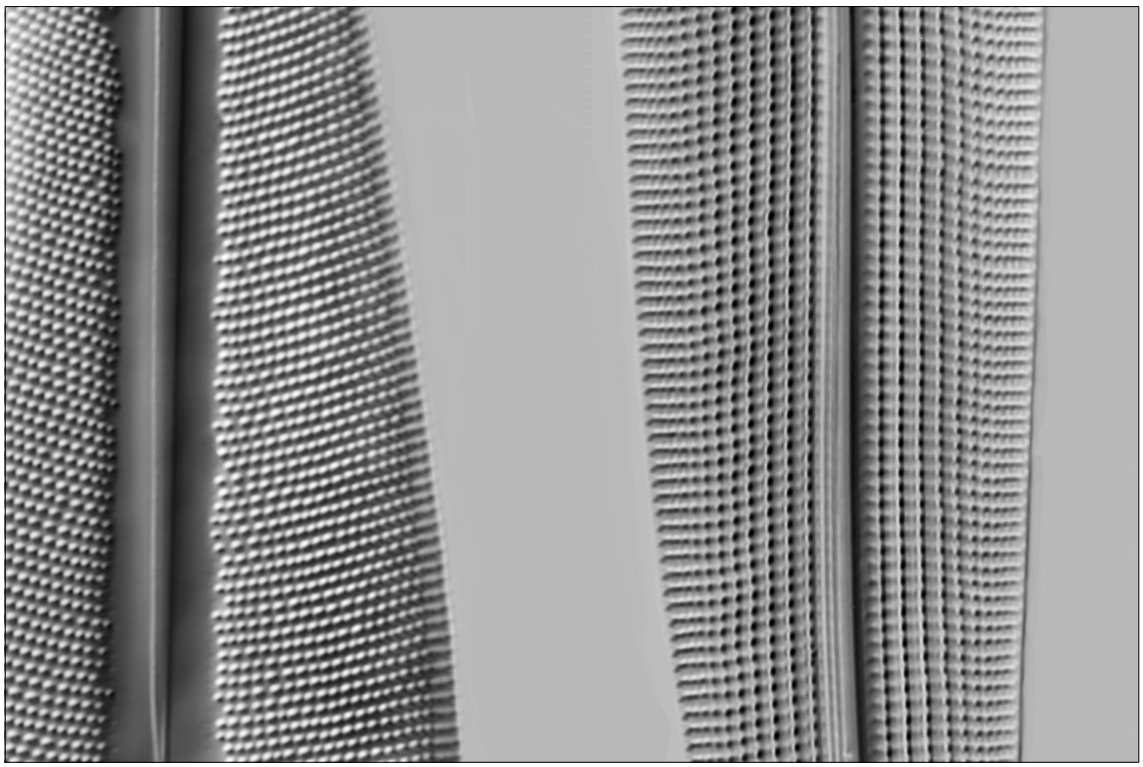


Photo 6) The first two diatoms of the slide Diatom Test Slide Version 2.0 . Here they are perfectly resolved in oblique illumination with the Carl Zeiss Jena 40x / 0.95 lens with correction ring, mounted on the LwdE microscope.

Photo 7) A summarized image of the Diatom Test Slide Version 2.0 produced and marketed by Diatom Lab. It is a standardized slide that allows to test the microscopes with dry and immersion objectives and in double immersion (= immersion objective + immersion condenser).

To date, I have never had the pleasure of seeing another Zeiss microscope up to the present day that includes an eyepiece Revolver, but it may be that with the publication of this article someone comes forward. Instead, it is sometimes possible to come across an Euskop microscope (produced by the aforementioned Fratelli Koristka) that mounts this type of revolver. Given the scarcity of information normally circulating, probably many Euskop owners will be aware of this trade name by reading this article. The Fratelli Koristka were absorbed in 1929 by the Officine Galileo of Florence, but did not cease to produce instruments bearing their own brand, at least until 1968, when it seems that the activity ceased and some former employees founded the COMP with a decidedly reduced production (9). The eyepiece revolver made by the Fratelli Koristka was marketed at least until about 1964 as it appears in the Micro 145 catalog of Fratelli Koristka SpA (personal communication of Dr. Giovanni Pietro Sini), where it is shown on the Euskop model (10). Regarding the year of production of the Euskop, I personally traced the related Patent by trade mark no. 86577 (first filing), which was filed November 7, 1947 at 11.15 by Fratelli Koristka SA at the Office Milan Depot. Actually, in the Micro 145 catalog, the Euskop Stand appears in three versions; the classic monocular model, the binocular model and the one with the eyepiece Revolver. In fact, defined in this case as a "prismatic eyepiece holder, with an inclined axis of 45°, with a rotating turret for 4 eyepieces". In this last version it usually had an Abbe condenser with NA 1.20 and an optical kit of the Fratelli Koristka brand composed of; 3 achromatic lenses (12x / 0.30; 45x / 0.85; 100x / 1.30) and 4 Huyghens eyepieces (6x ; 8x; 10x; 14x). Also available were the semi-apochromatic 100x / 1.32 immersion lens to be combined with the 9x and 12x compensating eyepieces, and the 15x periplanatic eyepiece. On request the

same Euskop model could be supplied with a condenser with NA 1,40, or a special condenser called BIRIS and defined as a "perfected Köhler system", provided with two iris diaphragms and illuminating system, having patent number 466686. As a curiosity, in the same catalog the BIRIS condenser is described as "especially indicated for the observation of fine structures and in microphotography, since it ensures the better lighting conditions at any magnification, through the appropriate use of the various condensation systems, the two mentioned above diaphragms and filters. In fact, it consists of; universal slide support, rack-type displacement, cylindrical body, with centering device, NA 0.95 final condenser, bayonet displacement, aperture diaphragm and relative aperture lens, field diaphragm and lens of field, illuminating device, with rapid exchange of the collecting lenses, one for the use of weak objectives, the other for medium and strong objectives; filter holder sector, rotating and able to swing out from the axis, with 2 filters; lamp body with 15W concentrated filament bulb and internal reflector; 20W power transformer, with multiple primary and variable secondary, cable and plugs". Moreover, in all Euskop models there is a very particular patented fine focusing movement (visible in the image of the catalog attached here), located above the horseshoe base, behind the lamp or mirror housing, while the coarse focus movement is for a rack controlled by two side knobs on the arm.

Photo 8) Euskop Microscope of the Fratelli Koristka equipped with Revolver of the eyepieces (the rotating turret is for four eyepieces, in the image the fourth eyepiece is hidden from the front one). Also see Photo10 at end of article.

Curiously – maybe according to Jung's ideas of synchronicity - during the writing of this article I came across a microscope of the aforementioned company COMP which in addition to having also the Revolver of the eyepieces (!), appears very similar to the Euskop of the Fratelli Koristka. The COMP Milan brand appears engraved frontally on the tube, together with the serial number 2033 and the name A. Ranzini, who according to some of my research was previously a collaborator of the Fratelli Koristka. It is therefore possible that that part of former employees of Fratelli Koristka SpA who decided to found the COMP - in addition to the experience gained previously - somehow recovered part of the design and (perhaps) of the equipment.

Thinking about the history of the Revolver of the eyepieces you could be misled by recalling the much older "Microscope à trois corps" present in the catalog Nachet et Fils of 1872 (but produced as early as 1856. A specimen is still preserved today the Department of Physiology of the University of Edinburgh). This fascinating instrument presented not four, but three eyepieces (see the attached image), with a further important difference: while the Revolvers of the eyepieces of brand Zeiss Jena, Fratelli Koristka and COMP allow to vary the magnification of the microscopic image by rotating the eyepieces with the possibility of observing each time from the selected eyepiece, the Nachet & Fils instrument appears more like a multi-discussion microscope as it guarantees simultaneous observation by three observers thanks to a special internal prism. In addition to the peculiar use of the "Microscope à trois corps" in the universities (the professor observed the preparation and commented on it while simultaneously showing it to the students), I like to mention “bourgeois salons” microscopy that I have already mentioned on other occasions. In the late nineteenth century with the strong expansion of the microscope even in bourgeois salons, where the landlord could amaze his guests by showing spectacular microscopic preparations such as micromanipulated diatoms and radiolaria.

Photo 9) The Microscope à trois corps (present in the catalog Nachet et Fils of 1872) can mislead us here. While the Revolvers of the eyepieces of brand Zeiss Jena, Fratelli Koristka and COMP allow to vary the magnification of the microscopic image by rotating the eyepieces with the possibility of observing from time to time only through the selected eyepiece, the Nachet & Fils microscope appears more like a multi-discussion instrument as it ensures simultaneous observation by three observers thanks to a special internal prism.

The disappearance from the Revolver the eyepieces from the market is not due to its appearance that many of us today might define a bit 'bizarre' or even antiquated, but the increasingly massive spread of binocular microscopes, in which it cannot be easily applied such a device. It is no coincidence that Zeiss Jena subsequently developed the Optovar already discussed earlier (and several competing companies created similar solutions), which can work in the presence of a binocular tube and any photomicrographic fittings.

The Revolver of the eyepieces has certainly had more luck in the field of telescopes, in this case there is an accessory also produced today (in versions with three or four positions), always with the function of quickly varying the magnification! Around 1914 there was a Zeiss Jena telescope called Starmor and equipped with Revolver eyepieces (12x, 24x, 42x), while in 1941 the same Zeiss Jena produced a limited edition telescope with an eyepiece Revolver (28x, 45x, 90x, 110mm), but out of catalog as it was expressly thought of as a military instrument intended for high offices.

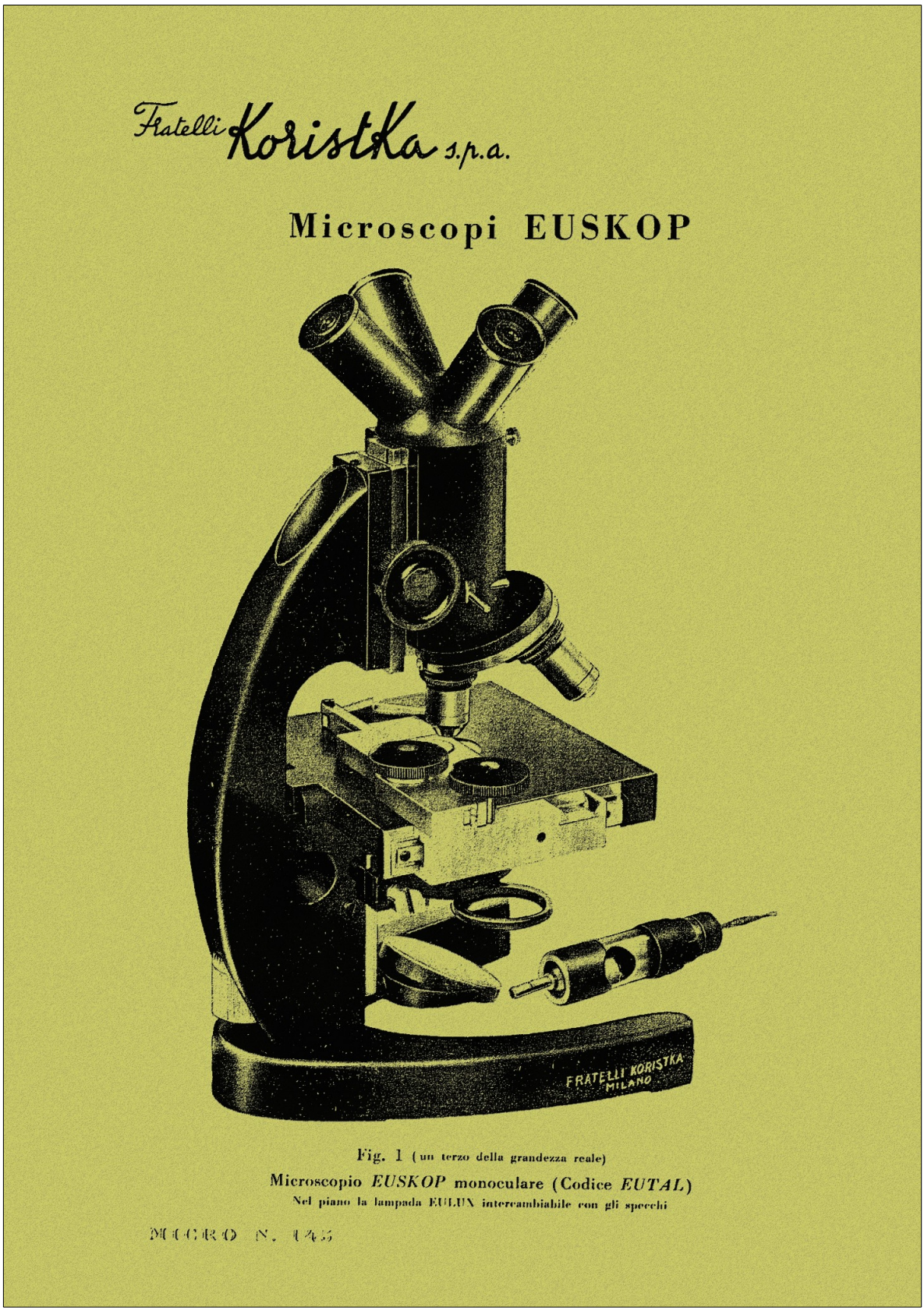


Photo 10) Euskop microscope shown in the Micro No. 145 catalog of the Fratelli Koristka SpA of Milan (1964).

Bibliographic notes:

(1) Carl Zeiss Oberkochen, *Zeiss Model W,* Zomi 04 542e, 1954
(2) Carl Zeiss Jena, *Zeiss Mikroskope und Nebenapparate*. Mikro 1, 1934 e 1939
(3) Carl Zeiss Jena, *Zeiss Microscopes*, Mikro 423/V e, 1937
(4) Carl Zeiss Jena, *Zeiss Mikroskope, Stative L,* Mikro 492/III, 1939
(5) Carl Zeiss Jena, *Zeiss Microscopes, Universal Stand Lu*, Mikro 542 e, 1940
(6) Carl Zeiss Jena, *Zeiss*, Mikro 11-035-1 SZ, 1940
(7) Koristka, C., *Il microscopio. I fondamenti ottici della visione microscopica e nozioni tecniche relative*, Ulrico Hoepli, Milano, 1930
(8) Autori vari, *Atti della prima manifestazione nazionale d'ottica*, Padova, 5-20 Giugno, 1927
(9) TURNER Gerard L'Estrange, *Microscopi, guida per il collezionista*, Silvana Editoriale, Milano, 1981
(10) Fratelli Koristka S.p.A., catalogo *Micro N. 145*, Milano, 1964

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