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SUPPLEMENTAL MATERIAL: TECHNICAL DETAILS ON PPM

The PPM is available from Marine Biological Laboratory (Woods Hole, USA) for dissemination to other users and can be manufactured per request (https://www.mbl.edu/bell/current-faculty/shribak-lab/).

An example of PPM principal optical scheme is shown in Fig. S2. The polychromatic polarizing module consists of two add-on units; the spectral polarization state generator and the achromatic left circular analyzer. The PPM can be added to a regular polarizing microscope with a white light source. We found that it is convenient to use a LED spot light bulb with tunable hue, for example Philips Hue PAR16 White and Color Ambiance Bulb (UPC 046677456672). The tunable light source allows to compensate a possible color shading in the image. An example of clinical/educational microscope Olympus CX21 equipped with PPM is shown here https://www.mbl.edu/bell/files/2014/12/PPM_2017-Shribak.pdf

The polarization state generator includes an achromatic right circular polarizer and a tilted plate made of gyrotropic crystal, which is cut perpendicular to the crystal optic axis, for example a c-cut quartz. Any optically clear and underformed quartz monocrystal can be used. If the quartz plate is perpendicular to the illumination beam the white circularly polarized light propagates through the plate along the crystal optic axis without change of the polarization state. The circular polarization is rotated, but it will be still the circular. However when the plate is tilted the polarization state generator produces polarized light with the polarization ellipse orientation determined by the wavelength, which we call the spectral polarization fan (Fig. S3). In particular we use a fan consisting of the right polarization ellipses, which covers the visible spectrum from 440nm to 660nm. The major axis of red polarization is oriented at 0º. Then the major axes of orange, yellow, green, cyan, and blue polarization ellipses are oriented at 30º, 60º, 90º, 120º and 150º, respectively. All polarization ellipses have the same ellipticity angle, ε~40º. If the specimen under investigation is not birefringent, then beam passes it without alteration of the polarization. The left circular analyzer will evenly partially transmit all wavelengths, and the output beam will stay white. If the object is birefringent, then it modifies the spectral polarization fan. The circular analyzer transmits more light if the ellipticity is increased and less light if the ellipticity is decreased. The particle color of the transmitted beam is determined by the suppressed spectral component. For example, a particle with phase retardation ~10º and the slow axis at 45º will add ~5º to the green polarization ellipticity angle and subtract ~5º from the red ellipticity angle. The green component will have the right circular polarization with ellipticity angle 45º, and it will be extinguished completely by the left circular polarizer. The red component will have ellipticity angle ~40º, and its transmission will be increased in ~4 times. So, the birefringent particle will be mostly red. If the particle is rotated by 90º then the green component will have ellipticity angle ~40º, and the red component will have ellipticity angle

~45º (right circular polarization). Therefore, the particle becomes green. When the particle is rotating by 180º its color is continuously changing in the entire hue range, from 0 to 1.

If the tilted plate is rotated around the microscope optical axis the polarization fan is also rotated accordingly. Then the image hue will follow. An example of image of dinosaur bone, which is illuminated by white polarized light with rotating spectral fan of polarization ellipses, is shown here https://figshare.com/articles/media/Dinosaur_bone_in_transmitted_light_under_polychromatic_polarized_microscope/14965710.

A dependence of hue on slow axis orientation was determined in the following experiment. We made a test waveplate with retardance 30 nm by crossing two retardation films with retardances 110nm and 140nm (Nitto Denko, Japan). The test waveplate was placed in PPM and rotated from 0º to 360º with step 20º. Eighteen images of the test waveplate are shown as a hue wheel in Fig. 1D. The initial slow axis orientation was horizontal. As we found the dependence of hue on the slow axis orientation angle is almost linear. In another experiment with rotated Wollaston prism we found that the hue practically does not depend on retardance amount. Thus, the slow axis orientation angle φ can be computed in the simple way:

$$\varphi = 180^{\circ} \cdot hue.$$

If the spectral polarization fan is rotated by 90º then the color becomes complementary (see Fig. 1C,D in the main text). This approach can be used in order to increase the image contrast of weak birefringent structures and eliminate the contribution from stained non-birefringent areas. We captured two PPM images with orientations of polarization fan at 0º and 90º. Exposure time of PPM images was ten times less than for the XPL image of the same subject. These bright-field images have the complementary hues produced by birefringence and the same colors generated by stain and/or light source. By subtracting one image from another, a differential image with double brightness is obtained.

The differential image has a dark background, reduced staining and removed non-birefringent structures because they are not affected by rotation of the polarization fan and therefore subtracted.

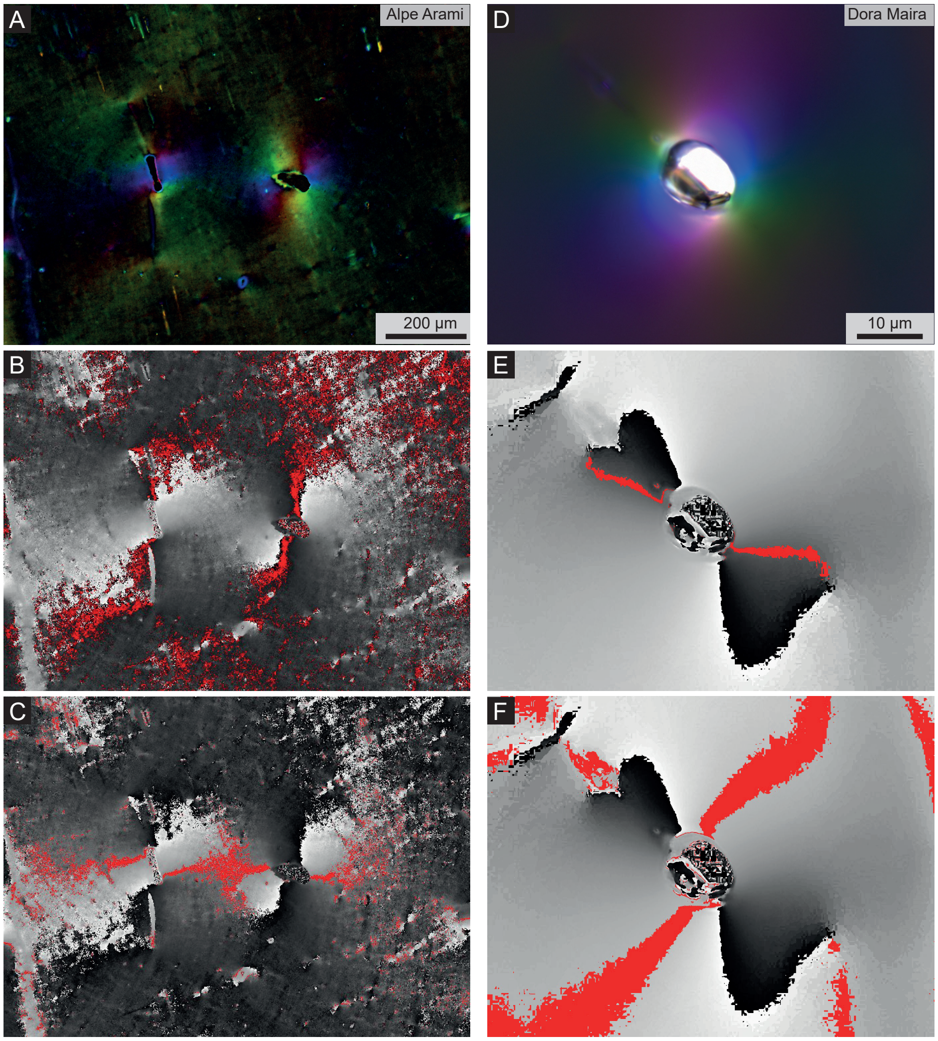


Figure S1. (A-C) Distribution of hues around two amphibole inclusions in a garnet from the Alpe Arami peridotite. (A) Differential PPM image. (B, C) Hue maps showing in red the distribution of hues in the ranges 12-28 and 130-145, respectively. (D-F) Distribution of hues around an inclusion of zircon in a garnet from the Dora Maira whiteschists. (A) Differential PPM image. (B, C) Hue maps showing in red the distribution of hues in the ranges 90-100 and 190-200, respectively.

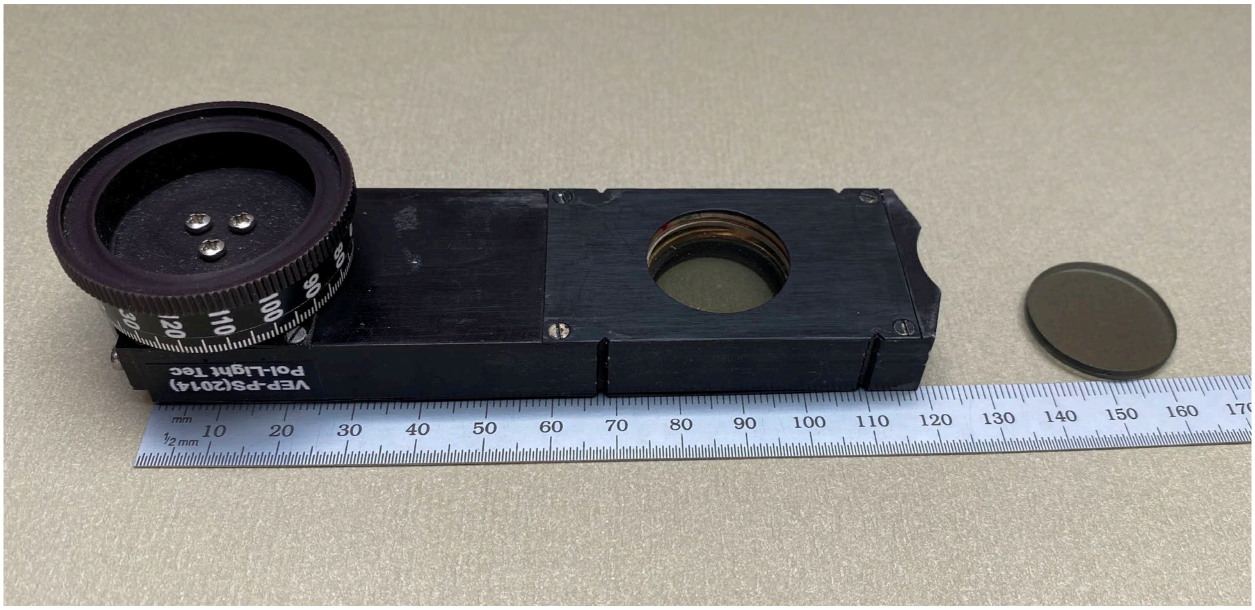
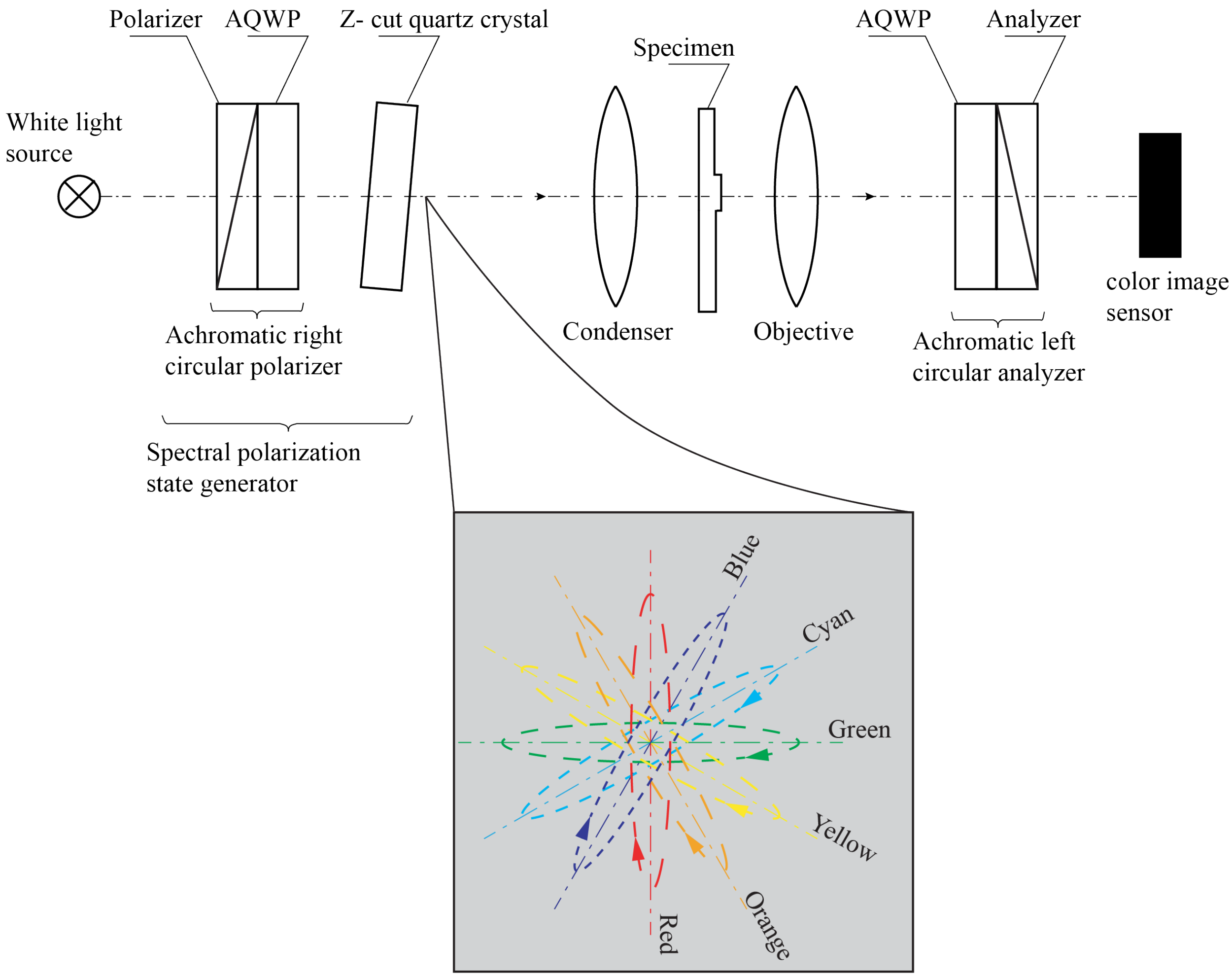


Figure S2: Photo of the two components of PPM: Spectral polarization state generator (left) and achromatic circular analyzer (right).



spectral fan of polarization ellipses

Figure S3: Scheme of the functioning of PPM, with spectral polarization fan on bottom.