Supplementary information

Ultrathin nonlinear metasurface for optical image encoding

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1. Linear transmission spectra for different rotation angles

As each meta-atom exhibits isotropic linear optical property due to the C3 symmetry. Therefore, the orientation angle does not affect the linear scattering process and the linear transmission spectrum does not change for different rotation angles. Figure S1 shows that for each rotation angle from 0° to 30° the transmission is equally strong, which means that neither the phase nor the scattering of the fundamental wave depends on the orientation of the meta-atom.

For observing the encoded image only in the SHG signal the meta-atoms need to have a C3 symmetry. For this symmetry group the linear response is isotropic with no Pancharatnam-Berry phase added to the scattered light field. Therefore, its orientation angle does not affect the linear scattering process or the phase of the light. However, C3 symmetric structures can generate SHG for circularly polarized light and the SHG signal contains a nonlinear Pancharatnam-Berry phase due to the rotation angle. Hence, the image can be encode in the orientation of the C3 structures without influencing the linear scattering properties.

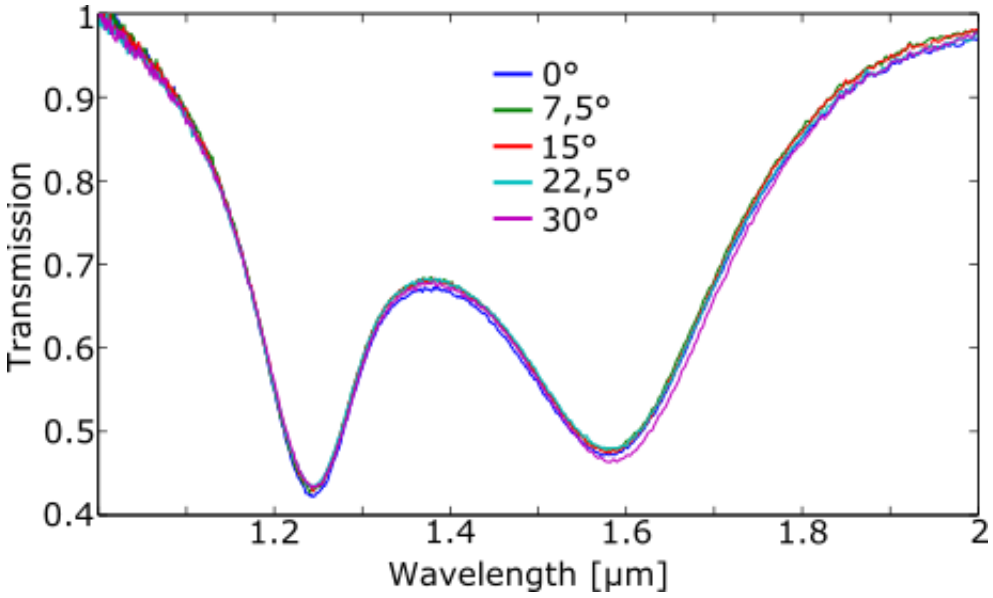

Figure S1. Linear Transmission spectrum for different rotation angles. Measured transmission spectrum of a metasurface made of C3 meta-atoms with unpolarized light for ration angles from 0° to 30°.

2. Rotation angle dependency of the SHG signal for linear polarized light

Since any linear polarized state can be described as a superposition of right and left circular polarization states, we expect the same rotation angle dependency for the SHG intensity under illumination with linear instead of circular polarized light. Figure S2 shows the measured intensities for vertically linear polarized light (compared to figure 2c). As expected it follows the function of $\cos^2(3\theta)$.

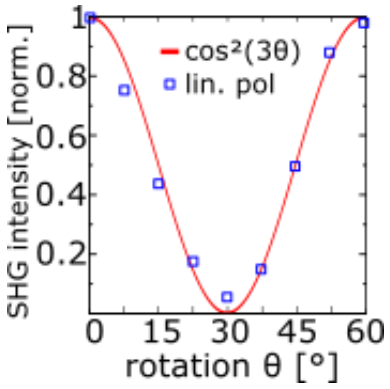

Figure S2. SHG intensities for linear polarized light. Angle dependent SHG intensity for excitation with a fundamental wave at 1250 nm wavelength for linear polarized light. The measured intensity shows the expected behavior based on the interference effect.

3. Additional reversed encoded images

With the same concept of tailored SHG intensities one can simply invert the image in the SHG signal by choosing $\theta = 0°$ for the background area and $\theta = 30°$ for the character (Figure S3a). The obtained image is the negative version of the previous design from Figure 4a. Now the letters appear dark on a bright SHG background. A similar result is obtained for the inverted design shown in Figure S3b, where the letters have different rotation angles.

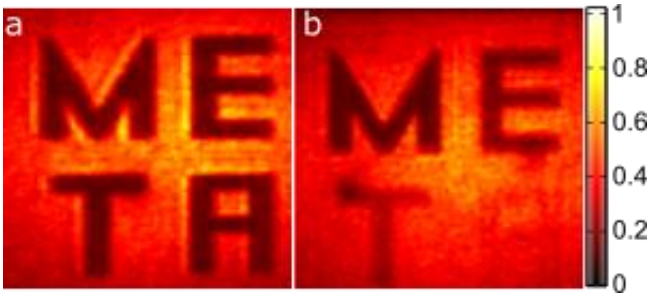

Figure S3. Inverted real space image of metasurface. a. Measured real space SHG image for the inverse design of Figure 4a. Now $\theta = 0°$ is used for the background and the character is made with $\theta = 30°$. b. Measured real space SHG image for the inverse design of Figure 4a.

4. Measurement setup

Figure S4 shows a schematic of the used set-up for the SHG measurements in figure 3. The beam from the OPO passes a linear polarizer and a quarter-wave plate. A lens then focuses the circular polarized light onto the sample, after it passes a long pass filter. The light is then collected by a 20x microscope objective. After the polarization state is analyzed with another quarter-wave plate and a linear polarizer the light passes a short pass filter and is coupled into a spectrometer. For the measurements of figure 4 the spectrometer is switched with a CCD-camera.

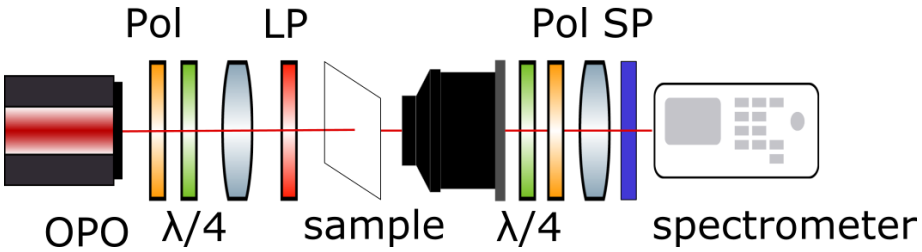

Figure S4. Set-up for SHG transmission measurements.