Topology is a science of shape. Typically, when one speaks about a shape, visible objects are in one's mind. However, the shape can refer to "objects" which are invisble just because they "live" in a space to which one has the access only through matematical constructions. These are abstract spaces, in which they are directions, planes, volumes and other types of shapes, but they can be only visible with the eyes of mathematics, and in particular - with the eyes of topology.

We shell be talking here about a special space in which "live", or which is said to be "spanned by", wave vectors, i.e., the vectors which describe direction of propagation of electromagnetic waves and the wave length. An electromagnetic wave is characterized with a frequency ω: this is the frequency with which the electric and magnetic fields of the wave oscillate around zero. One can ask a question: what are wave vectors which correspond to the wave of the frequency ω?

Well, the answer depends on the medium in which the wave propagates. The simplest case is a medium which is isotropic, i.e., its properties do not depend on direction. One can say that an electromagentic wave with the frequency ω is the same irrespective of the direction in which propagates: the wave vectors of these waves are all of the same length, irrespective of direction of propagation. Let's take all of these vectors corresponding to all possible directions (an infinite number of them!) and put their origins at one point. Then, their ends will lie on a sphere. In this way, we generated a shape - a sphere - in an abstract space, where the wave vectors "live". This shape is named an "isofrequency surface" because ω is the same for all considered wave vectors.

That was simple, let us take a more complicated example. There are natural materials which are called uniaxial in which - as the name suggests - there is one direction which in some sense is "different" from others. This difference is reflected in a way electromagnetic waves propagate in such a crystal: the length of the wave vectors depends on the direction of propagation. There is a mathematical formula which describes this dependence, but let us pass by this complication and let us repeat the construction we have done before. We gather the origins of the wave vectors at one point and then we find out that their ends are distrubuted over a rotational ellipsoid which axis of rotation coincides with this special direction in the uniaxial medium. Again - this is the shape that we can only imagine, but we know that it is there because we are confident that mathematics and topology acts equally well in any space - being it real or not!

Another question one could ask is the following: is it possible to pass from a sphere and an ellipsoid? The answer is positive, and known for ages. Just take an isotropic medium, and make one direction diffrent from others. How to do this? You can press in one direction, you can put the medium in an electric or magnetic field, or find yet another solution. That is somehow astonishing: you manipulate with the medium in the real space and you change shapes in an abstract space!

Things are even more interesting in the case of artificially fabricated materials in which the isofrequency surface is a heperboloid. This happens almost never in natural compounds but can occur in certain range of ω in materials called hyperbolic metamaterials, composed of interleaved conductive and isolating layers. A hyperbolid is drastically different from a sphere or an ellipsoid: the wave vectors can be infinitevly long and this has profound consequences on propagation of electromagnetic waves in such media. One can change the shape of the isofrequency ellipsoid to hyperboloid by changing external factors like temperature. We then say that an optical topological transition has occured.

This is the aim of the project: to observe how properties of a material at THz frequencies change when the material is or not a hyperbolic metematerial. We expect that this will chane the time of response, sensitivity of detection and effectiveness of emission of THz radiation.