Until recently, all known solid state materials have been divided in condense matter physics to two categories – *metals* and *insulators*. This fundamental classification is based on the ability of solid to conduct electrical charge, even at temperatures equal to absolute zero. It has been assumed that such property is specific only to metals. However, new theoretical studies have shown, that the list of known solids must be extended by the addition of a new category – the *topological insulators*.

In this novel type of materials the electrical current can flow as well – even at temperatures equal or close to absolute zero – but only on the *surface* of the solid samples. Therefore, the bulk volume of a crystal behaves like an insulator, whereas its boundary is perfectly metallic. Moreover, the origin and properties of currents, which flow on the bulk/vacuum boundary of *topological* insulators, are so special and unexpected, that they deserve a new direction in solid state physics, recently called in the literature as *Topotronics*.

The recipe for *2-dimensional* topological insulator is as following: take a thin (with a thickness about 100 Å) crystal layer sandwiched between top and bottom layers, made of insulating material with a larger band gap. Structure of this type is called a quantum well because the energy of internal electron states depends not only on the effective masses, but also on the well thickness d. The value of d must be selected in such a way, that the valence band is energetically above the conductivity band. Finally, fabricate from the inverted quantum well a conducting channel of length L and width W, terminated with electrical contacts, using lithography. At the side boundaries of the channel the surface states with linear dispersion are formed, as shown in Fig. 1. In this case they are called *edge currents*.

The above recipe sounds simple, however up till now, it has only been successfully applied to mercury telluride (HgTe) crystals and to double quantum wells made of indium arsenide and gallium antimonide (InAs/GaSb). The presence of surface states has been confirmed, nevertheless, their properties show significant discrepancies between experiments and theoretical predictions. Therefore, further refinements of the recipe are necessary, yet the required technologies are available only to few international laboratories. Among them are two polish scientific centers – Rzeszów University (HgTe quantum wells) and Institute of Electron Technology in Warsaw (InAs/GaSb double structures). This fact was the direct motivation for the scientific content of our project. In its first stage we plan to refine and optimize the fabrication technology of 2-dimensional *topotronic* structures.

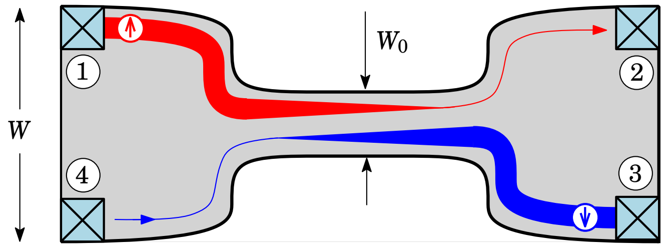

Fig. 1 An example of a *topotronic* structure, which will be investigated in our project. Channel of width W has been narrowed to $W_0 \ll W$ by the internal constriction. Here, the edge currents are so close to each other, that the magnetic moment of carriers may change its direction due to weak interactions with crystal lattice. As a result, we can perform the *logical operations* on an electron spin. For example, with electrical current flowing between contacts (1) and (3), the spin flips by 180 degrees.

The proposed investigations belong, for the main part, to the domain of basic research. The theoretical and experimental studies will be devoted to the analysis of physical mechanisms which may reduce the electrical conductivity of zero-mass charge carriers. As shown on Fig. 1, two edge currents, flowing in opposite directions, exist at each channel boundary and both of them carry electrons with the opposite sign of internal magnetic moment (the so-called *spin*). To reverse the current flow *at the same edge*, the presence of a magnetic field is needed, because the electron spin must be flipped by 180 degrees when the direction of motion is changed. Therefore, if strong magnetic interactions are absent, zero-mass electron cannot scatter back, this is the so-called *topological protection*. Such protection is, however, ineffective when the electron scatters across channel width to the *opposite edge* of the sample. Mechanism of this type are related to defects in quantum well structure and, among others, will be subject of our investigations.

The robustness of topological currents against defects and impurities which are located on channel edge makes our project interesting also from the perspective of possible applications. Optimization of the recipe for preparing 2-dimensional topological insulators will allow the incorporation of topologically protected edge currents to the active regions of fast field-effect transistors and spintronic devices. The example of such structure is shown of Fig. 1.