A single substance can give glass different colours

The oldest archaeological fnds of coloured glass are from several thousand years ago. Glassmakers have tested their way to an understanding of how glass can be produced in all the colours of the rainbow. They added substances such as silver, gold and cadmium and then played with diferent temperatures to produce beautiful shades of glass. In the nineteenth and twentieth centuries, when physicists started to investigate the optical properties of light, the glassmakers' knowledge was put to use. Physicists could use coloured glass to flter out selected wavelengths of light. To optimise their experiments, they started to produce glass themselves, which led to important insights. One thing they learned was that a single substance could result in completely diferently coloured glass. For example, a mixture of cadmium selenide and cadmium sulphide could make glass turn either yellow or red – which one it became depended on how much the molten glass was heated and how it was cooled. Eventually, they were also able to show that the colours came from particles forming inside the glass and that the colour depended on the particles' size. This was more or less the state of the knowledge at the end of the 1970s, when one of this year's laureates, Aleksey Yekimov, a recent doctoral graduate, started working at the S. I. Vavilov State Optical Institute in what was then the Soviet Union.

Aleksey Yekimov maps the mysteries of coloured glass

The fact that a single substance could result in diferent coloured glass interested Aleksey Yekimov, because it is actually illogical. If you paint a picture in cadmium red, it will always be cadmium red, unless you mix in other pigments. So how could a single substance give glass of diferent colours? During his doctoral degree, Yekimov studied semiconductors – important components in microelectronics. In this feld, optical methods are used as diagnostic tools for assessing the quality of semiconducting material. Researchers shine light on the material and measure the absorbance. This reveals what substances the material is made from and how well-ordered the crystal structure is. Yekimov was familiar with these methods, so he began using them to examine coloured glass. After some initial experiments, he decided to systematically produce glass that was tinted with copper chloride. He heated the molten glass to a range of temperatures between 500°C and 700°C, varying the heating time from 1 hour to 96 hours. Once the glass had cooled and hardened, he X-rayed it. The scattered rays showed that tiny crystals of copper chloride had formed inside the glass and the manufacturing process afected the size of these particles. In some of the glass samples they were only about two nanometres, in others they were up to 30 nanometres. Interestingly, it turned out that the glass' light absorption was afected by the size of the particles. The biggest particles absorbed the light in the same way that copper chloride normally does, but the smaller the particles, the bluer the light that they absorbed. As a physicist, Yekimov was well acquainted with the laws of quantum mechanics and quickly realised that he had observed a sizedependent quantum efect (fgure 3). This was the frst time someone had succeeded in deliberately producing quantum dots – nanoparticles that cause size-dependent quantum efects. In 1981, Yekimov published his discovery in a Soviet scientifc journal, but this was difcult for researchers on the other side of the Iron Curtain to access. Therefore, this year's next Nobel Prize Laureate in Chemistry – Louis Brus – was unaware of Aleksey Yekimov's discovery when, in 1983, he was the frst researcher in the world to discover size-dependent quantum efects in particles foating freely in a solution