# Luminescence thermometry – novel approach to enhance the range, sensitivity and accuracy of measurements

## 1. The research goal and/or hypothesis

The purpose of the proposed research is to develop new luminescent materials with spectroscopic characteristics adequate for particularly demanding applications in the measuring range (several hundred degrees from helium), sensitivity and accuracy of temperature measurements. Materials will be characterized by properties that outperform the currently known systems. In particular, a single material will allow temperature measurements within the range of at least 600 °C, with a sensitivity level of not worse than 10%/K for the helium range and not worse than 1%/K for temperatures of ~ 500-600 K. The level of accuracy of the temperature determination will not be lower than 0.1 K for helium temperatures and not worse than 2 K for temperatures in the range of 500-600 K. We plan to undertake research work that allows us to widen the measuring range to 800 K or even above. **We are going to achieve these goals by applying a completely new approach to designing luminescent temperature sensors.**

## 2. Research method/methodology

The research can be divided into three main stages: (i) the synthesis of materials with the highest homogeneity of properties, (ii) measurements of emission spectra and their kinetics in the widest possible range of temperatures - minimum 20-600 K, and (iii) analysis of obtained experimental results to determine parameters relevant for remote temperature measurements by luminescent techniques. Regarding (i), it is very important to achieve a high homogeneity of luminescent properties, which will involve refining the synthesis methods used, possibly by changing it to the so-called wet techniques. This may not be a big challenge, but it is important to be aware of the need for such research. The most important steps will be (ii) and (iii). Both require extraordinary precision and critical evaluation and analysis of results. Point (ii), measurements, requires the availability of high-end equipment. The team in this area is already reasonably equipped. Planned purchases would increase this level to very good, allowing for measurements of the highest precision required for studies on such materials. Measurement of emission spectra (also spectra of luminescence excitation, which, however, do not have to be extremely precise in terms of resolution, for example) and emission kinetics must be conducted using the most severe regime, including noise reduction and measurements repeatability.

## 3. Wpływ spodziewanych rezultatów na rozwój nauki

Preliminary studies indicate that we have discovered a luminescent material that is characterized by an unprecedented set of parameters relevant for remote luminescence temperature measurement. In particular, $Sr_2GeO_4$:Pr allows to measure, using one sample (!), Temperatures in the range of 17-600 K, which is already the best achievement ever reported in the literature. The same sample shows the highest sensitivity compared to the literature data in terms of cryotemperature reading up to 75 K. This is a very important area in space research and missions. Also sensitivity of this sensor is the best among reported in literature. These initial results are **fantastic, but they only open up a field of research that we hope to fill in with new content in terms of designing new materials for luminescent thermometry**.

In our opinion, it is not an accidental fortune that $Sr_2GeO_4$:Pr has such good parameters as a luminescent temperature sensor. So far, the possibility of improving the luminescent parameters of the temperature sensors has been sought, for example, by double doping of the matrix with the classical system $Yb^{3+}$,$Er^{3+}$ (there were, of course, also others). Core-shell systems were also used which were *de facto* “two-sensor systems in a single package”. In $Sr_2GeO_4$:Pr unique properties for temperature sensing are achieved due to the presence of three different emissions generated exclusively by the $Pr^{3+}$ ion. These are: (i) 5d$\rightarrow$4f emission in the UV range; (ii) $^3P_0$ emissions mainly in the green-blue range (~ 480-500 nm) and (iii) red emission, which is a mixture of $^3P_0$ and $^1D_2$ emissions. Because these emissions exhibit different temperature dependencies, using this fact it is possible to measure temperatures in a wide range by comparing their mutual intensities. It will not be an exaggeration to say that this is completely new approach in the field of luminescence temperature sensors, yet simpler than previous ideas in terms of the ability to control and manage processes. **We are confident that we are opening a new chapter in research into materials for luminescence thermometry.** Despite $Sr_2GeO_4$:Pr, we plan to deeply research also $Sr_2(Ge,Si)O_4$:Pr, $Y_2SiO_5$:Pr and $Y_2(Si,Ge)O_5$:Pr, as this composition also show potentials for high performance in luminescent thermometry. The Si,Ge mixed materials are expected to allow to manage nonradiative relaxation processes in the materials and thus enhance their performance as luminescence temperature sensors.