The main focus of the project is to research and examine the possibility of reaching the photocurrent gain > 25 with the excess noise < 2 in HgCdTe avalanche photodiodes (APDs) operating at longwave infrared radiation (LWIR) range (with cut-off wavelengths $\lambda_c \sim 8$ μm) with either 4- ($T > 190$ K) or 2- stage thermoelectrical (TE) cooling. Mentioned research would encompass an approach to determine the LWIR APDs' structure and technology development of the device by basic/fundamental research (HgCdTe layer growth on GaAs substrates and *processing*). Within the project it is planned to determine whether it is possible to reach the gain > 25 of the photocurrent under high operating temperature (HOT) conditions, and what factors have a decisive influence on the avalanche effect in analyzed HgCdTe APDs. Our initial results show that HgCdTe exhibits low gain in HgCdTe photodiode designed for MWIR spectral range and fabricated using metal-organic chemical vapor deposition (MOCVD-on GaAs substrate). Maximum gain of about 3 was observed under 8 V and temperature 180 K. That value is order of magnitude lower than the published in the literature, however reached in completely different temperature condition ($T = 77$ K) and much higher voltages. Therefore, we claim that the reached result must be treated as rational, with the potential prospect for the future work on extending the cut-off wavelength to the LWIR range ($\lambda_c \sim 8$ μm) due to the fact that the analyzed nominal heterostructure has not been optimized for the avalanche effect. It must be underlined that higher performance in terms of gain and excess noise in LWIR HgCdTe APDs operating without cryogenic cooling may be reached by improving the detector's architecture to include absorber and multiplications regions and improvement of growth and *processing* procedures.

Why HgCdTe for LWIR APDs? HgCdTe is an industry material for the fabrication of infrared detectors for critical and strategic applications covering the important IR range from 1.3 to 16 μm. Asymmetry between the effective masses of electrons and heavy holes results in an unequal ionization coefficient for electron and hole in HgCdTe. In addition, HgCdTe has a highly favorable electron to hole impact ionization ratio for different compositions from $x_{Cd} = 0.1$ to 0.7. High avalanche gain can be reached with low noise as the multiplication process is initiated by a single carrier - electron injection for lower x_{Cd} - values ($x_{Cd} < 0.6$) or hole injection for $0.6 < x_{Cd} < 0.7$. The dominant carrier multiplication process can be limited to one type of carriers in HgCdTe based APDs. Currently, the highest performance of the LWIR HgCdTe APDs has been reached at 77 K (gain 114 under 5 V). The leading groups in IR technology to include DRS Technologies, CEA-LETI, BAE systems are working on the development of HgCdTe APDs operating at LN_2. Having the experience in HgCdTe HOT MWIR and LWIR detectors we believe that the numerical simulation will allow to design an optimal LWIR HgCdTe APDs operating without LN_2 cooling. In the next stage the technological parameters allowing to fabricate device structures will be determined. The HgCdTe heterostructures will be grown using the MOCVD on GaAs substrate. Next, the grown heterostructures will be characterized by classical methods used in IR detectors technology. The structure, optical, and photoelectrical properties will be assessed. The results of this work will be employed to improve the detector's architecture (geometry, active area, multiplication region and contact layers doping optimization) and technological parameters crucial for their fabrication.

APDs are useful for the detection of low power optical signals in the space based imaging applications. APDs with high bandwidth (BW) and internal gain are suited for the detection of attenuated optical signals as in battle field conditions and long range applications offering a combination of high speed, high sensitivity and high quantum efficiency. APDs are an attractive choice for many IR applications such as night vision, LIDAR/ LADAR, and free - space optical communications (FSO - fibreless photonics) where LWIR range is much more favorable than mid- or short wavelengths (MWIR, SWIR). In addition, the two main detrimental scattering effects of Rayleigh and Mie are significantly reduced within LWIR in comparison to the MWIR. Although many applications, where APDs could be potentially implemented there is one fundamental limitation - APDs require LN_2 cooling (77 K). APDs fabricated with $A^{III}B^{V}$ materials (InAs, InAlAs, InGaAs for 0.3 μm $< \lambda_c < 1.7$ μm) show high excess noise at high gain values due to the fact that both carriers are involved in the multiplication process leading to the fact that $A^{III}B^{V}$ APDs requires extremely high applied voltage for multiplication. The excess noise factor for $A^{III}B^{V}$ APDs is reported to be in the range 4–5 while APDs' BW stays within the range 300–400 GHz. In order to meet SWAP (*size weight and power*) conditions there is a high demand to increase operating temperature to the level of either 4- or 2- stage TE cooling. That could be reached by the material where multiplication process is initiated and limited by one type of carriers. HgCdTe gives that possibility.

Tasks to be undertaken in this project are new and original compared to the previously implemented. That have significant benefits, for example enabling reduction of the device's SWAP requirements and what is most important, reduction of cost of production (lack of the LN_2 cooling). In addition, research on extending of the IR technology into military applications, into science and environmental protection, especially for field applications where LN_2 cooling is impossible or very difficult to be deployed are extremely important.