Glasses are peculiar materials that lack the regular atomic arrangement characteristic for crystals. While glasses are amorphous which means that their atomic order resembles the frozen structure of a liquid, they are mechanically rigid and macroscopically act like solids. The usual route to make a glass is supercooling i.e. quenching a viscous liquid from above melting point down to so called glass transition fast enough to bypass crystallization. The vitreous state of matter, like volcanic glasses occurs naturally and have been used extensively by humans since Stone Age. Later on, Egyptian craftsmen begun production of synthetic silicate glasses by melting of sand. Since then, different kinds of glasses became crucial for many industrial applications and are currently common in the everyday life.

Over time, glasses tend to transform into their crystalline counterparts corresponding to a lower energy state. The ability of a liquid to form a glass and the stability of the glassy state result from hampering the tendency of atoms to arrange into crystalline configuration. Liquids can considerably differ in their glass-forming ability and the cooling rate required to avoid crystallization. For example, silica melt can be easily quenched into a glass, since the atomic motion in silica substantially slows down on supercooling. On the other hand, metallic liquids are typically poor glass formers and metallic glasses are known only since a half of a century. The intrinsic reluctance of liquid metals to form glassy phase on quenching is related to exceptionally fast atomic dynamics below the melting point where crystallization is most likely to occur. Due to this time-scale limitation, following the transition between the different states of a supercooled metal is a major challenge and the fundamental mechanisms underlying the formation and stability of metallic glasses remain essentially unknown.

The key idea of the current project is to overcome this limitation by exploiting the unique capabilities of the ultra-short laser pulses. Our idea of an ultrafast time-domain approach to monitor crystallization of metallic glasses is based on repetitive laser heating to temperatures ranging from glass transition up to the melting point. In this approach, a thin film a metallic glass is heated at the rate of 10^{14} K/s and after a short transient of tens of picoseconds (1 ps=10^{-12} s) is quenched at 10^{12} K/s by heat transfer into the film substrate. Our aim is to obtain quantitative information on the relevant transformation rates of different metallic glasses. Through a combination of a fast heating and quenching using short laser pulses with structure-sensitive characterization techniques we will follow the structural pathways of the material between its glassy and crystalline phase. The research program involves probing the state of the material with optical, X-ray and electron pulses which will let us explore the time domain from a microsecond (1 μs=10^{-6} s) down to a picosecond. The state-of-the-art approach will let us clarify some most puzzling issues concerning formation and stability of glassy metals. Namely, we will follow for the first time rapid crystallization of metallic glasses in the critical region of maximal transformation rate. Our study will give insight into the essential for vitrification but previously unexplored regimes of crystal nucleation and growth kinetics in metallic glasses. The proposed ultrafast time-domain approach will provide a broad knowledge on crystallization rate which will be a significant step towards fundamental understanding of formation of glassy metals.