To make prospective sustainable technologies more economically feasible, a new way of catalyst design is needed. Catalysts are now continuously improved by changing their composition and nanostructure. However, there are boundaries to how active catalysts can be, because the interaction of reaction intermediates with the catalyst must be balanced: not too strong and not too weak, but just right. This is a compromise.[1] An emerging approach to overcome these boundaries is that of resonant catalysis (RC). In RC, catalysts are stimulated by an intermittent stimulus, such as light, mechanical stress or electric fields, at high frequency (Hz-MHz), in order to change the interaction with reaction intermediates at the time scale of the reaction itself, so that the activity is not limited by a specific step of the reaction. RC theory predicts an enhancement in catalytic performance up to 3 orders of magnitude above the maximum predicted by the well-known Sabatier principle (Figure 1).[2] Despite the promising RC predictions, only mild (up to 2 times) enhancement in catalytic activity has been shown experimentally so far by intermittent stimulation, because the stimulus-catalyst interactions are not well understood and the choice for stimulation parameters was so far based on trial and error.[3]

Therefore, this project is focused on developing high time-resolution (up to 109 Hz, ns) *operando* infrared (IR) spectroscopy tools, based on step-scan IR methods, to observe the effect of the stimulation on catalysts at work. We will use light as a stimulus and focus on the CO2-to-methanol (MeOH) reaction because of societal relevance and existing challenges in catalytic performance.[4] We will determine the relationship between the light stimulation parameters, catalytic performance, and the type and dynamics of the reaction intermediates formed during stimulated catalysis in the CO2-to-MeOH reaction, to boost activity by a factor of 10 with respect to continuous illumination.