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Light-driven reaction networks: turning light energy into chemical work

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Dipartimento di Scienze e Tecnologie Chimiche

Proponente Dott. Daniele Mazzarella

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Light is a convenient energy source for chemistry. It can be controlled in space and time and tuned in intensity and wavelength; in clean photochemical reactions, heat is the only waste produced.[1] When photochemical steps are coupled to thermal reactions, light can drive the whole network away from equilibrium, making endergonic processes possible.[2] Reaction networks can therefore be designed to turn light into a desired type of work. In this framework, ratchet mechanisms[3] offer a way to obtain the desired function, provided that the kinetics of the network are finely controlled.

In this seminar, I will discuss some examples of how light energy can be transduced within a chemical system. The first is a molecular motor whose direction of rotation is set by the wavelength of irradiation.[4] I will then move from motion to self-assembly: under illumination, a host–guest system accumulates a diastereomeric complex disfavored at equilibrium.[5] The last examples deal with active transport. Between the two arms of a U-tube, light pumps ions against their concentration gradient,[6] while at the molecular scale a light-powered pump actively collects macrocycles from solution onto its axle.[7]

These examples point to the same concept: light energy has to be dissipated to perform chemical work, and kinetic asymmetry in the network is a requirement for doing so. This network-based approach, established in the field of molecular machines, is general in scope. In the final part, I will discuss how it could be extended to other areas of chemistry, such as catalysis, where light can also be used in less conventional ways, for example by modulating it in time.

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[7] F. Nicoli, C. Taticchi, S. Corrà, M. Tranfić Bakić, M. Baroncini, S. Silvi, J. Groppi, A. Credi, *Angew. Chem. Int. Ed*. **2026**, 65, e8103353.

Short scientific profile – Dr. Federico Nicoli

Federico Nicoli studied Biological Sciences (BSc) and Chemistry (MSc) at Sapienza University of Rome. He received his PhD in Chemistry from the University of Bologna in 2022, working with Prof. Alberto Credi on light-driven molecular machines. His thesis was awarded the "Prof. Gian Piero Spada Medal" for the best PhD thesis of the Department of Chemistry, University of Bologna. After two years as a postdoctoral researcher in Bologna, in 2024 he joined the group of Prof. Giulio Ragazzon at ISIS, University of Strasbourg, to work on light- and chemically-driven active transport, and he still collaborates with the group.

His research focuses on the kinetics and mechanisms of chemical and light-driven reaction networks, which he studies by combining synthesis and spectroscopy with quantitative kinetic modeling. His interest in systems chemistry began during his studies in biology, where complex systems are understood as networks rather than as isolated reactions. His work has been published in journals including Nature Chemistry, JACS, Angewandte Chemie and Chem.