

CESQ Colloquium

Friday September 18 @ 11 AM

Seminar Room, Centre Européen de Sciences Quantiques,
Campus de Cronenbourg

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From Molecular Qubits to Quantum Sensors through Materials Chemistry

This century is witnessing a second quantum revolution, and quantum sensing represents an area in which chemists can make significant contributions. Chemically engineered molecular quantum sensors are compact and allow for precise control of their structure. Achieving quantum sensing requires more than precise control of quantum states at the molecular level; it is also crucial to organize qubits into molecular quantum system so that they function effectively in complex environments. In this talk, I will discuss materials chemistry approaches to molecular quantum sensors, focusing on their extension from biological systems to engineered materials.

We have recently enabled intracellular quantum sensing by developing a molecular quantum nanosensor (MoQN) [1]. By encapsulating atomically optimized molecular spin qubits within biocompatible nanocrystals, MoQNs achieve highly uniform spin energy levels and enable room-temperature optical detection of molecular spin states inside living cells. Compared with existing nanoscale quantum sensors, MoQNs exhibit superior uniformity, making absolute temperature sensing within cells possible—an achievement that has been challenging to realize with conventional platforms.

I will then show how molecular quantum sensing can be extended into chemically programmable materials. By incorporating photoactive chromophores as components of metal–organic frameworks (MOFs), these MOFs enable spatial organization and chemical accessibility of molecular qubits. This design allows quantum sensors whose spin coherence times respond to surrounding chemical species at room temperature [2,3]. Finally, I will discuss how controlled molecular assembly leads to multilevel quantum states (qudits). Through precise chromophore arrangement, singlet fission generates spin-correlated quintet triplet pairs with submicrosecond quantum coherence, expanding molecular quantum sensing beyond two-level systems [4,5].

Together, these examples illustrate how materials chemistry transforms molecular qubits from isolated spin systems into versatile sensing platforms that function across biological and materials environments.

- [1] Hitoshi Ishiwata, Jiarui Song, Yoko Shigeno, Koki Nishimura, Nobuhiro Yanai, [Science Adv. 2026, 12, eaeb5422](#).
- [2] Akio Yamauchi, Nobuhiro Yanai, [Acc. Chem. Res. 2024, 57, 2963–2972](#).
- [3] Akio Yamauchi, Saiya Fujiwara, Nobuo Kimizuka, Mizue Asada, Motoyasu Fujiwara, Toshikazu Nakamura, Nobuhiro Yanai, [Nature Commun., 2024, 15, 7622](#).
- [4] Akio Yamauchi et al., [Science Adv., 2024, 10, eadi3147](#).
- [5] Wataru Ishii et al., ChemRxiv, [DOI: 10.26434/chemrxiv.15001885/v1](#).

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