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Fast multiphoton imaging of embryonic development in vivo: from motile cilia to the beating heart

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Multiphoton microscopy has demonstrated unique advantages for imaging embryonic development *in vivo*, including deep imaging or the ability to combine nonlinear fluorescence excitation with label-free contrast mechanisms, such as second or third harmonic generation. However, the acquisition speed is often a critical limitation for multiscale imaging or for investigating fast biological phenomena, such as motile cilia, biological flows or the beating heart. We will present optical and computational strategies that we have developed in recent years to circumvent or overcome this limitation. Indeed, we will show how light-sheet illumination or biological periodicities and imaging artifacts, can be exploited to capture and study processes of extreme dynamics deep inside a living embryo. For example, we have been able to capture multicolor or label-free multiphoton signals in a beating embryonic heart with millisecond time resolution, to resolve the blood flow at micrometer scales, to record neuronal activity in an entire developing brain, to study beating cilia or to quantify the microscopic flows they generate that break left-right symmetry deep inside the embryo. Capturing and quantifying such dynamic processes provides new insights into embryonic development and opens up new possibilities for understanding this fascinating event.

Affiliation de l'auteur principal

Laboratory for Optics and Biosciences, CNRS - INSERM - Ecole polytechnique

Auteur principal: Dr SUPATTO, Willy (Laboratory for Optics and Biosciences (LOB) - Ecole Polytechnique - CNRS - INSERM)

Orateur: Dr SUPATTO, Willy (Laboratory for Optics and Biosciences (LOB) - Ecole Polytechnique - CNRS - INSERM)

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