Summary of the ICFA Workshop Subgroup on "Time-Resolved Techniques and New Laser Development"

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Time-resolved x-ray experiments can be undertaken in nearly all field of physical and biological research. Sub-picosecond studies with visible light lasers are currently a very active area of research, and collaborations between laser and x-ray experts were felt to be very advantageous to advance the state-of-the art of time-resolved x-ray techniques. The focus of the discussion in this subgroup was laser-pumped/x-ray-probed experiments. There was considerable discussion on the interaction of the high intensity x-ray beams with matter, from detrimental issues, (sample damage) to exciting possibilities and applications (e.g., x-ray nonlinear phenomena). However it is clear that these issues are not unique to time-resolved studies.

Two broad frontiers of scientific research using sub-picosecond x-rays were discussed: measurements of (induced) structural changes (through scattering and/or EXAFS techniques) and the evolution of electronic excitations (via scattering and NEXAFS techniques). As the discussion progressed it became clear that, to perform and interpret any of these experiments, it is extremely important to: (1) maximize the amount of information collected from each burst of x-rays (efficient detectors), (2) ensure the timing between the pump and probe is accurately known (with an accuracy at least equal to the width of the x-ray pulse itself), and (3) understand the effect of the (x-ray) probe beam on the sample.

Time-resolved pump/probe experiments naturally fall in to two categories: single-shot experiments and stroboscopic experiments. In some sense, single-shot experiments are the simplest to perform but may require so many x-rays on the sample to get the information out that the probe itself may alter (damage) the sample. Stroboscopic experiments require less intensity per pulse (of both the pump and the probe) and therefore may reduce sample damage. However this technique inherently requires a sample that can be either reversibly be excited or be replenished. The time structure of the LCLS (sharp spikes several femtoseconds wide within an envelope several hundred femtoseconds in width repeating 10 to 100 times per second) is very well matched to the pulse duration and repetition rate of currently available femtosecond lasers, thereby optimizing the use of both the (laser) pump and (x-ray) probe energy. Although the "spikiness" of the time structure was generally considered a inconvenience, the possibility of taking advantage of that time structure to push temporal resolutions to several femtoseconds is an exciting possibility and needs to be more carefully looked into. The limitations on temporal resolution that result from the diffraction process itself must also be considered and how that may ultimately limit the temporal resolution of time-resolved experiments. Other proposed time structures (such as the TESLA project with many pulses in a macro-bunch) may also have interesting applications to time-resolved studies and the flexibility of this macro-bunch train should be exploited for different types of experiments and timescales. This subgroup was not familiar enough with the accelerator physics of FELs to resolve specific questions about their time structure. Hence it was felt that certain "parameters" need to be better clarified so that a better assessment of the potential capabilities of the x-ray FEL can be made. (The flexibility of the timing of the pulses in the macro-bunches, the bunch-to-bunch jitter of pulses in the pulse train and, what is the limit of the bunch lengths (can they be made shorter and what would the trade-offs be), etc.). Or, to reverse the situation, this group needs to come up with a list of FEL parameters that we would find advantageous for time-resolved studies. That will be one of the goals of this working subgroup over the next 9 -12 months.

There was considerable discussion of the need for detector improvements and handling/storage of data, in particular high-speed area detectors (the speed depends on the details of the temporal characteristics of the source) and the use and application of (sub-picosecond) streak cameras. Finally it is clear that femtosecond lasers, synchronized to the x-ray bursts, will be an integral part of a 4^{th}-generation x-ray facility if time-resolved experiments are to be seriously pursued.