Instrumentation and moderators at long pulse neutron sources

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The guiding principle at the design of a long pulse neutron source is to maximize the time-integrated brightness of the moderated neutron pulses emitted to the instruments. At a given instantaneous rate of fast neutron production and moderator efficiency, the time-integrated brightness is proportional to the pulse length of the fast neutron generation. The upper limit of the pulse length is set to correspond to the lowest incoming wavelength resolution aimed at within the priority instrumental applications. In the case of ESS, this lowest wavelength resolution was defined at around 10 % by the needs of the cold neutron small angle scattering (SANS) instruments of common and affordable geometrical dimensions, i.e. about 30 m total length and typically 1 cm diameter beam area on the sample. With the integrated intensity of the neutron pulses optimized this way, higher wavelength resolution can be delivered individually at different instruments and for different experiments on the same instruments by the use of pulse shaping mechanical neutron choppers systems. The pulse repetition rate of the source needs to be kept for reasons of operational costs and efficiency to the lowest without considerable loss in total data collection performance. This lowest efficient pulse repetition rate strongly depends on the instrument design. The multiplexing time-of-flight methods recently developed for use on pulsed sources make possible to extract several neutron pulses on the sample from a single source pulse according to the needs of the different instruments and experiments. For the source pulse parameters of ESS (about 3 ms length at 14 Hz repetition rate), the effective shaped pulse length and pulse repetition rate delivered by the specific multiplexing chopper systems of the various instruments can vary between about 0.01 ms to 3 ms and 7 Hz to 200 Hz, respectively. These instrument design methods have already been implemented, tested and in routine standard use at operating neutrons facilities, both reactors and short pulse neutron sources. The optimization of the time-integrated brightness per pulse also calls for special neutron moderator-reflector system design approaches, such as enhanced brightness by directional neutron emission at quasi low-dimensional moderator shapes and multi-spectral beam extraction. All of these approaches have been extensively studied and validated by simulation calculations at ESS and SNS, and bi-spectral beam extraction is in routine at the Berlin reactor since a decade.