

AN IGBT PULSER FOR THE NONLINEAR INJECTION KICKER AT TAIWAN PHOTON SOURCE

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Abstract

A test unit pulser for the proposed NIK (nonlinear injection kicker) project at TPS (Taiwan Photon Source) was fabricated in order to provide uniform kick strength applying onto the injected bunch train. This newly built flattop pulser gives much improved drive current pulse shape in comparison with previously used half-sine pulser. This flattop pulser will result in high injection efficiency and provide adjustable capability in terms of bunch train filling pattern.

INTRODUCTION

Feasibility of implementing sextupole injection at TPS (Taiwan Photon Source) has been tested previously with 300 mA stored electron beam. The associated injection scheme in terms of injection trajectory and sextupole location has proven to be effective and deserved further exploration [1, 2]. In the meantime, several synchrotron light sources around the world developed much improved top-up injection technique by using an NIK (nonlinear injection kicker) so as to eliminate any possible injection disturbance to the stored electron beam [3, 4]. Using the previously demonstrated injection trajectory and tested injection scheme, implementing an NIK at TPS to replace the existing four injection kickers turns into a feasible choice to uplift its beam injection quality so as to provide transparent injection to the users. Among many of the suggested improving requests for a transparent injection to the TPS user, a flat-top pulser with fall-time shorter than 1 microsecond becomes one of the most challenging technical item. Consequently an IGBT based flat-top pulser is considered and therefore fabricated in this case to replace the existing half-sine pulser. In this report, we briefly described the status of this IGBT pulser. Its engineering performance is presented.

ANALYSIS

The layout of injection scheme for the proposed NIK injection at TPS is shown in Fig. 1 and Fig. 2. Fig. 1 gives injection trajectory at the very end of BTS (Booster to Storage ring) transfer line where the NIK is located at the injection straight section. Tuning of the beam trajectory for sextupole injection appeared to be straight forward. Only a pair of horizontal correctors at the end of BTS transfer line and the injection septum were involved with moderate adjustments. A ceramic chamber between the existing kicker-3 and kicker-4, previously used for sextupole installation,

will be replaced by the NIK during the next TPS shutdown period. Figure 2 depicts the first several turns of the corresponding phase space tracking of the injected electron beam for illustration purpose.

In Fig. 1, tuning of beam trajectory at the transfer line guides the electron arriving NIK with injection angle of $x' = 3.2$ mrad at $x = 15$ mm. The NIK kicks the injected electron trajectory in parallel with beam centerline while leaving the stored beam undisturbed. The revolution time of the storage ring is about 1.7 microseconds. The operational bunch train in present routine user shifts is set at 0.7 microseconds. Since the newly built flat-top pulser shuts off within 1 microsecond, the one-turn injected electron beam gives turn-by-turn tracking pattern in Fig. 2. The injected electron beam will eventually merge into the stored beam at centerline due to various damping mechanisms in few millisecond [5].

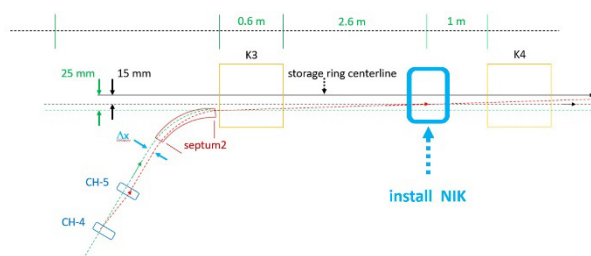


Figure 1: The NIK locates at the injection straight section sitting between kicker-3 and kicker-4. The injected beam trajectory (in green) at the end of BTS transfer line is for the routine four kickers injection scheme while the steered beam trajectory (in brown, using CH-4, CH-5, septum2) is for NIK injection consideration (CH: horizontal corrector).

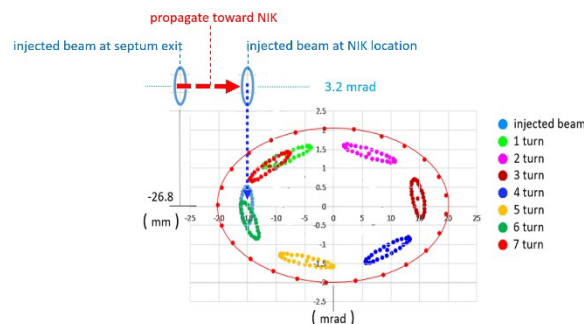


Figure 2: Phase-space tracking of the injected electron beam at NIK location for the injection and subsequent several turns under routine horizontal fractional tune $\nu_x = 0.16$.

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Since 5 mA is top-up filling to the TPS 500 mA stored electron beam within each routine 10 injection shoots, the 0.1% beam increment at every shoot would then be transparent to the users.

THE IGBT PULSER

The specifications of the proposed NIK flat-top pulser is listed in Table 1. Since the kick strength of NIK requires drive current of 1600 A and fast turn-off with fall-time less than 1-microsecond, none of the available IGBT in hands fulfils the need. We therefore put two IGBT modules (BEHLKE: HTS61-160FI) in parallel for testing purpose in order to meet the specifications required [6].

Table 1: NIK Pulser Specifications

Parameter	Specification
Current (A)	1600
Flat-top (μsec)	> 0.7
Flatness (%)	0.5
Fall time (μsec)	< 1
Stability (%)	0.1
Load (μH)	1.6

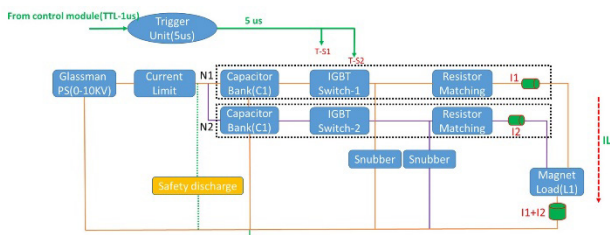


Figure 3: IGBT pulser circuitry.

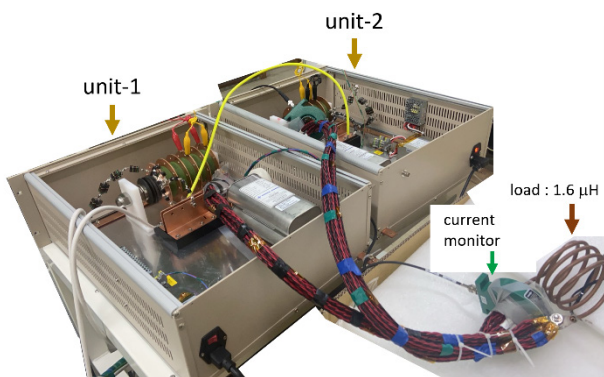


Figure 4: Photo of the IGBT pulser (unit-1 and unit-2) test unit assembling.

Figure 3 shows the layout of IGBT pulser circuitry. Figure 4 gives photo of whole set of parallel arranged IGBT modules, the associated charging capacitors and inductance matching accessories as well. Field experience indicates that fine touching of electronic ground loop for the pulser assembling appears to be sensitive and critical to

noise suppression so as not to interfere with the IGBT triggering processes. It has to be carefully deal with so as not to blow up the IGBT in worst case.

Typical pulser delivering current is displayed in Fig 5. The achieved total delivered current of 1800 A would meet the specification required, as given in Table 1. The pulser turns off duration is less than 1 microsecond. Since the full current output takes longer time to achieve due to circuitry design, one could adjust capacitor for proper charging and the specified current. As for the current jiggle observed at the IGBT turning-off instant in unit-2 is nevertheless bothersome. Countless field trials to eliminate the current jiggle give no significant improvement. Consequently a compromised option was chosen to acquire a single IGBT module (BEHLKE: HTS91-360FI) for the test unit in consideration of project schedule required.

While switching over from two parallel IGBT module to a single IGBT module in Fig. 3, the pulser circuitry impedance and its ground loop tuning has to be redone and carefully deal with so as to eliminate various noises associating along IGBT trigger signal. The newly built single IGBT pulser gives reasonable linearity of its delivering current versus charging voltage, as shown in Fig. 6.

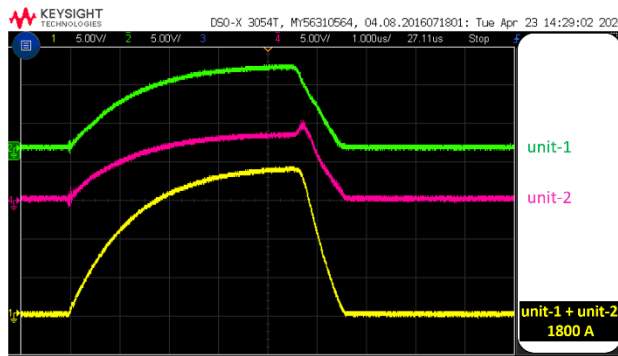


Figure 5: Current pulse shape of the IGBT pulser.

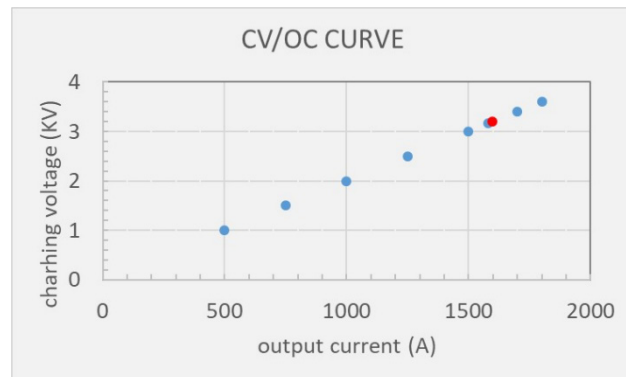


Figure 6: The single module IGBT pulser gives linearity of its delivering current versus capacitor charging voltage. The red dot in the figure represents the specification of delivering current at 1600 A with its corresponding charging voltage of 3.2 kV.

A primitive test result of the single IGBT pulser appears in Fig. 7. It shows that the delivered 1800 A current shuts off in less than 700 ns. Long period observation during pulser reliability test run indicates that the pulse-to-pulse stability of applicable flat-top over 1 microsecond span is better than 0.1%, as shown in Fig. 8.

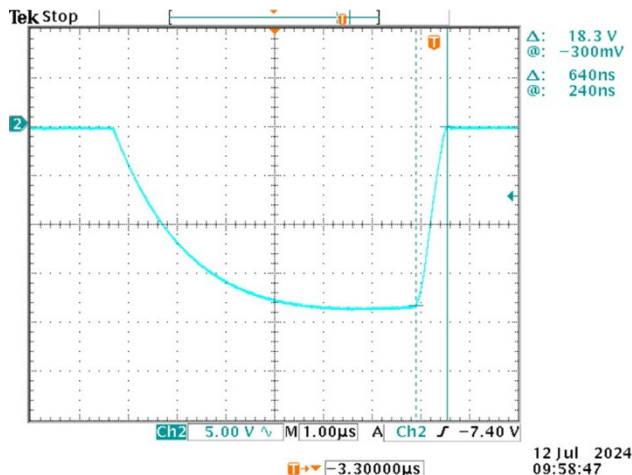


Figure 7: The single module IGBT delivers 1800A and it shuts off within 700 ns.

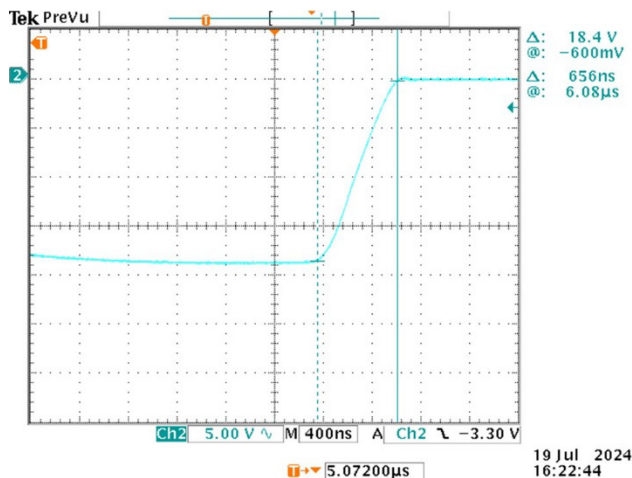


Figure 8: The flat-top of delivered 1800 A spans over 1 microsecond. The pulse-to-pulse stability is better than 0.1%.

SUMMARY

We have fabricated two types of IGBT pulsers that are capable of delivering 1800 A for the NIK project. These pulsers provide flat-top spanning of 1 microsecond and fall time of 700 ns. The pulse-to-pulse stability is better than 0.1%. The first type is using two IGBT in parallel operation and the other is a single IGBT with high output current capacity. For the observed testing results and for pulser circuitry integration consideration, a single IGBT pulser appears to be superior to the two module in parallel operation. It is worth of noting that IGBT module of high output current capacity is not generally available as needed. Also, some IGBT associated circuitry has to be fine tuning for

each of the individual IGBT module. It indicates that both a spared IGBT module and/or a backup pulser unit has to be carefully examined beforehand.

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