Pulse Current Analysis at BESSY II

Talk at PulPoKS workshop 2023

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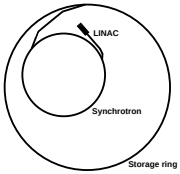
Table of Contents

Table of Contents

Introduction & Motivation

- BESSY II
  - Maximum electron energy = 1.7 GeV
  - Operated in top-up mode
  - More than 10 pulsed magnets used for extraction and injection
- Pulse-View-Program (PVP)
  - Originally set-up in framework of top-up operation
  - Now essential for high injection efficiencies of $\approx 98\,\%$



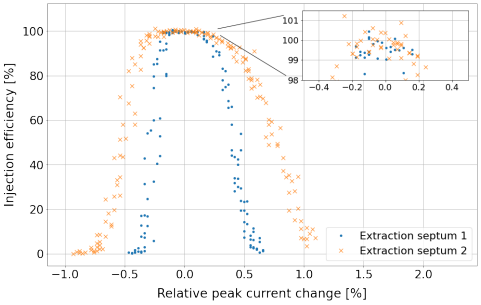


Table of Contents

Pulse-View-Program

- Measurement of pulse current with pulse current transformer and digitizer card
- Determines pulse current amplitude in arbitrary units & time of fwhm

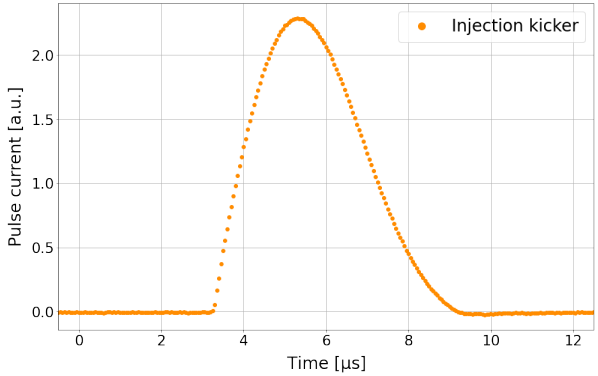
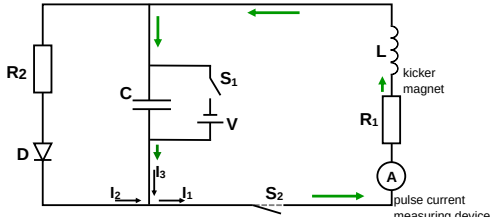
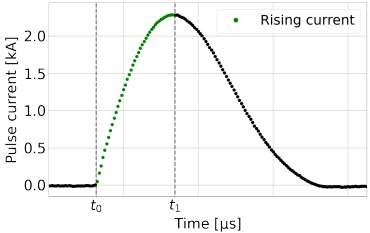


Table of Contents

Replacement Circuit

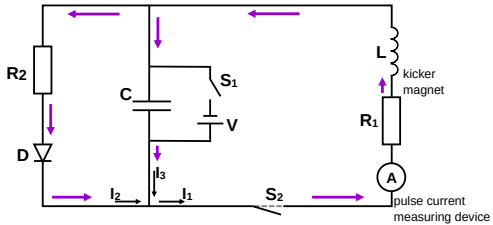
- Two parts
  - Rising current: $t \in [t_0, t_1]$
    - $\rightarrow$ $I_{\text{rising}}(t) = -Q_0 \cdot \frac{\omega_0^2}{\omega_1} \cdot e^{-k_1 \cdot t} \cdot \sin(\omega_1 \cdot t)$

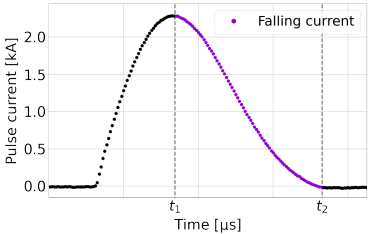




Replacement Circuit

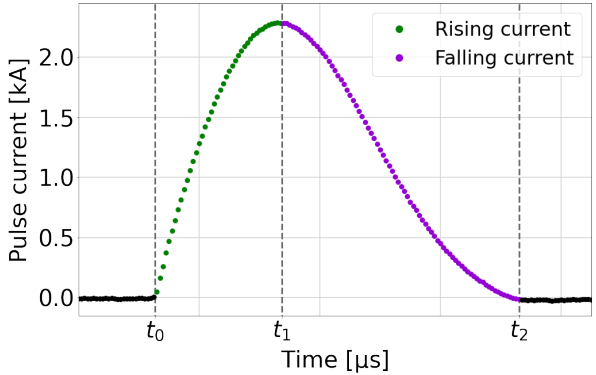
- Two parts
  - Rising current: $t \in [t_0, t_1]$
  - Falling current: $t \in [t_1, t_2]$
    - $\rightarrow$ $I_{\text{falling}}(t) = d \cdot e^{(a-k_1)\cdot(t-t_1)} \cdot \left[\cos\left(c \cdot (t-t_1)\right) + \frac{k_1 - a}{c} \cdot \sin\left(c \cdot (t-t_1)\right)\right]$





Model

$$I_{\text{model}}(t) = \begin{cases} 0 & , t < t_0 \ \& \ t > t_2 \\ I_{\text{rising}}(t) & , t_0 \leqslant t < t_1 \\ I_{\text{falling}}(t) & , t_1 \leqslant t \leqslant t_2 \end{cases}$$



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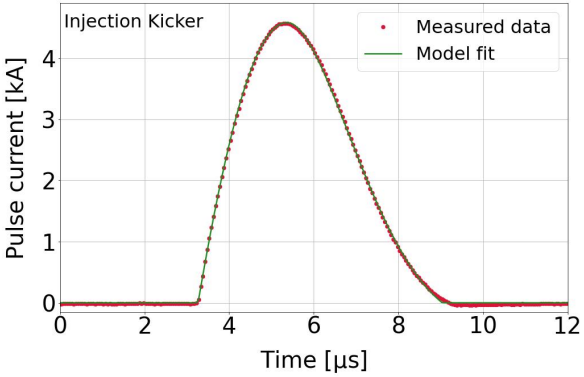
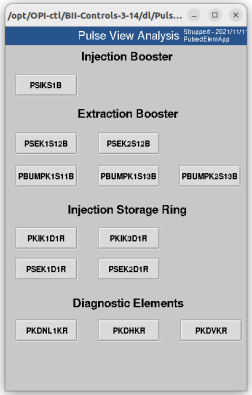
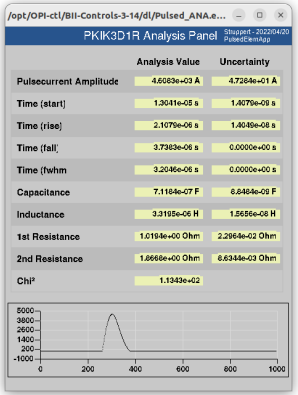


Online Pulsed Element Diagnostics

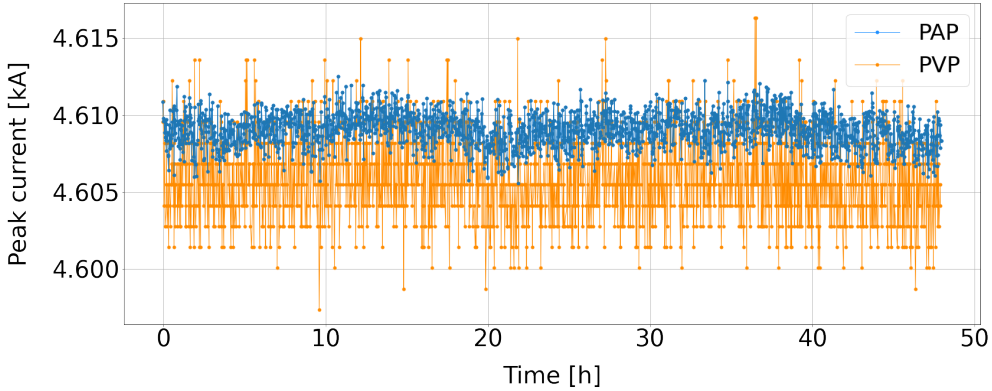
- Pulse-Analysis-Program (PAP) implemented in control system
- Allows extraction of I_{Peak}, t_0, t_{rise}, t_{fall}, t_{fwhm}, C, L, R_1, R_2, Q_0
- Enables new observations





Online Pulsed Element Diagnostics - Performance analysis

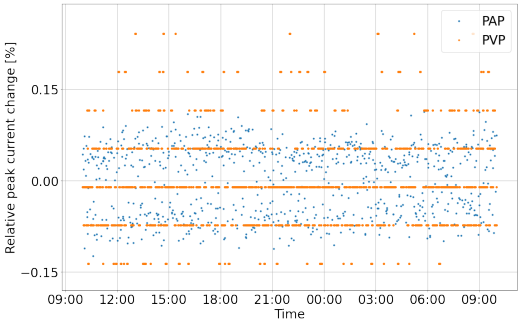
- Peak current of kicker in storage ring:

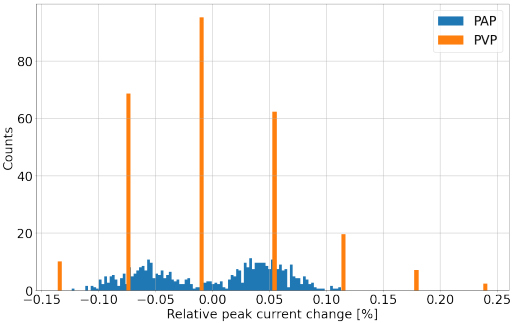


→ Reduced scattering of determined peak current

Online Pulsed Element Diagnostics - Performance analysis

- Relative peak current change of bumper in booster:

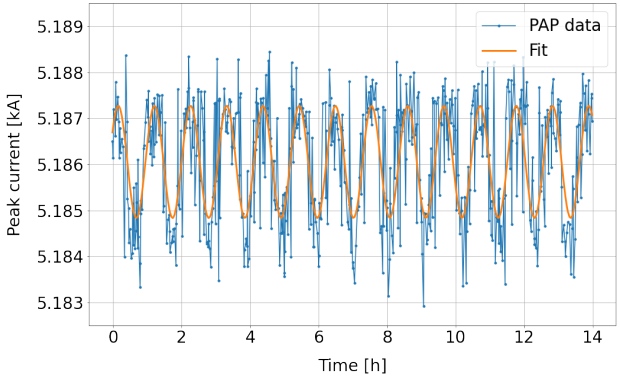




→ Increased statistical significance

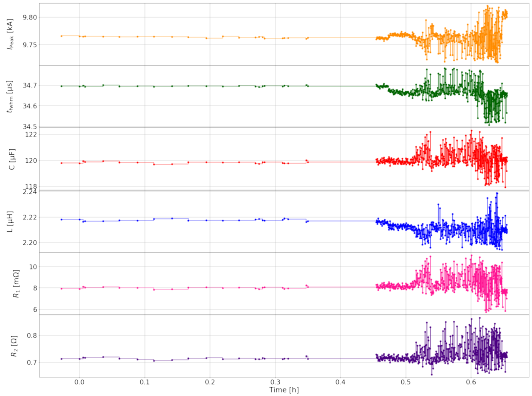
Online Pulsed Element Diagnostics - Example Observations

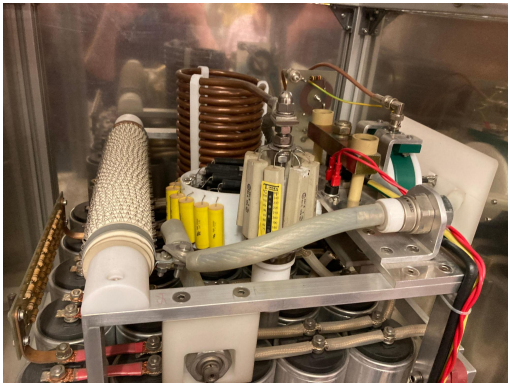
- Periodic disturbance of second extraction septum of booster
- Fit:
  $I_{Peak}(t) = a \cdot \sin(b \cdot t + c) + d$
  $\rightarrow \; f = (262.5 \pm 0.9)\,\mu\text{Hz}$
- Source of disturbance not yet found



Online Pulsed Element Diagnostics - Limits

- After shut down observation of anomalous behaviour of injection septum:





→ No inference from physical fit parameters to real components possible

Table of Contents

Conclusion & Outlook

- Model to describe pulsers provides good analysis of pulse current measurement
- Implementation in control system enables online diagnosis of pulsed elements
- New observations could be made

- Next steps:
  - Implement model for full-wave pulsers
  - Develop model for rectangular pulsers

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I would like to thank the following people (in alphabetical order) for their help.

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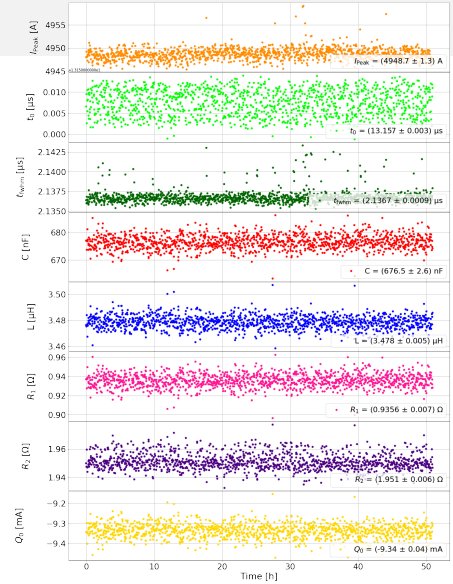
PAP Results I

Example quantities of the two storage ring injection kickers at BESSY II determined with the established model for a kicker pulse in standard user operation

Quantity		Kicker 1	Kicker 3
I_{Peak}	[kA]	(4.95 ± 0.05)	(4.61 ± 0.05)
t_{rise}	[µs]	(2.136 ± 0.015)	(2.109 ± 0.014)
t_{fall}	[µs]	3.759	3.742
t_{fwhm}	[µs]	3.244	3.206
C	[nF]	(674 ± 9)	(715 ± 9)
L	[µH]	(3.480 ± 0.017)	(3.314 ± 0.015)
R_1	[Ω]	(0.929 ± 0.026)	(1.027 ± 0.022)
R_2	[Ω]	(1.957 ± 0.010)	(1.861 ± 0.008)
Q_0	[mC]	(-10.12 ± 0.13)	(-9.87 ± 0.12)

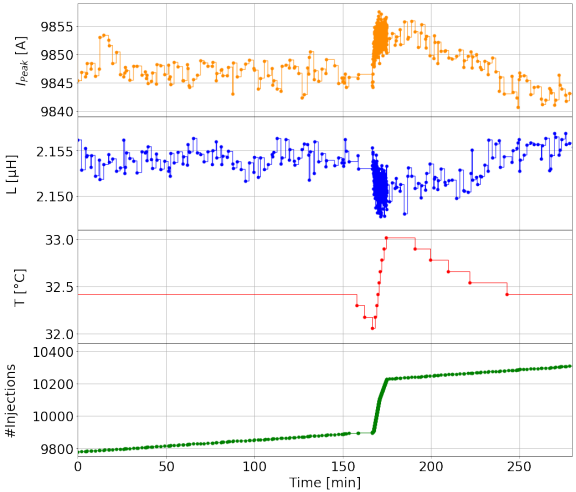
PAP Results II

Parameters of a storage ring injection kicker during 51 h of standard user operation of BESSY II determined with the PAP, as well as their mean value and standard deviation



PAP Results III

Peak current of the second injection septum of the storage ring and corresponding inductance determined with the Pulse-Analysis-Program (PAP) as well as the temperature of the septum and the number of injections



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