The semi-digital spectrometric system for positron spectroscopy

R.S. Laptev, A.A. Mikhaylov, Y.S. Borbulev, G.V. Garanin and A.M. Lider

National Research Tomsk Polytechnic University, 634050, Tomsk, Russia

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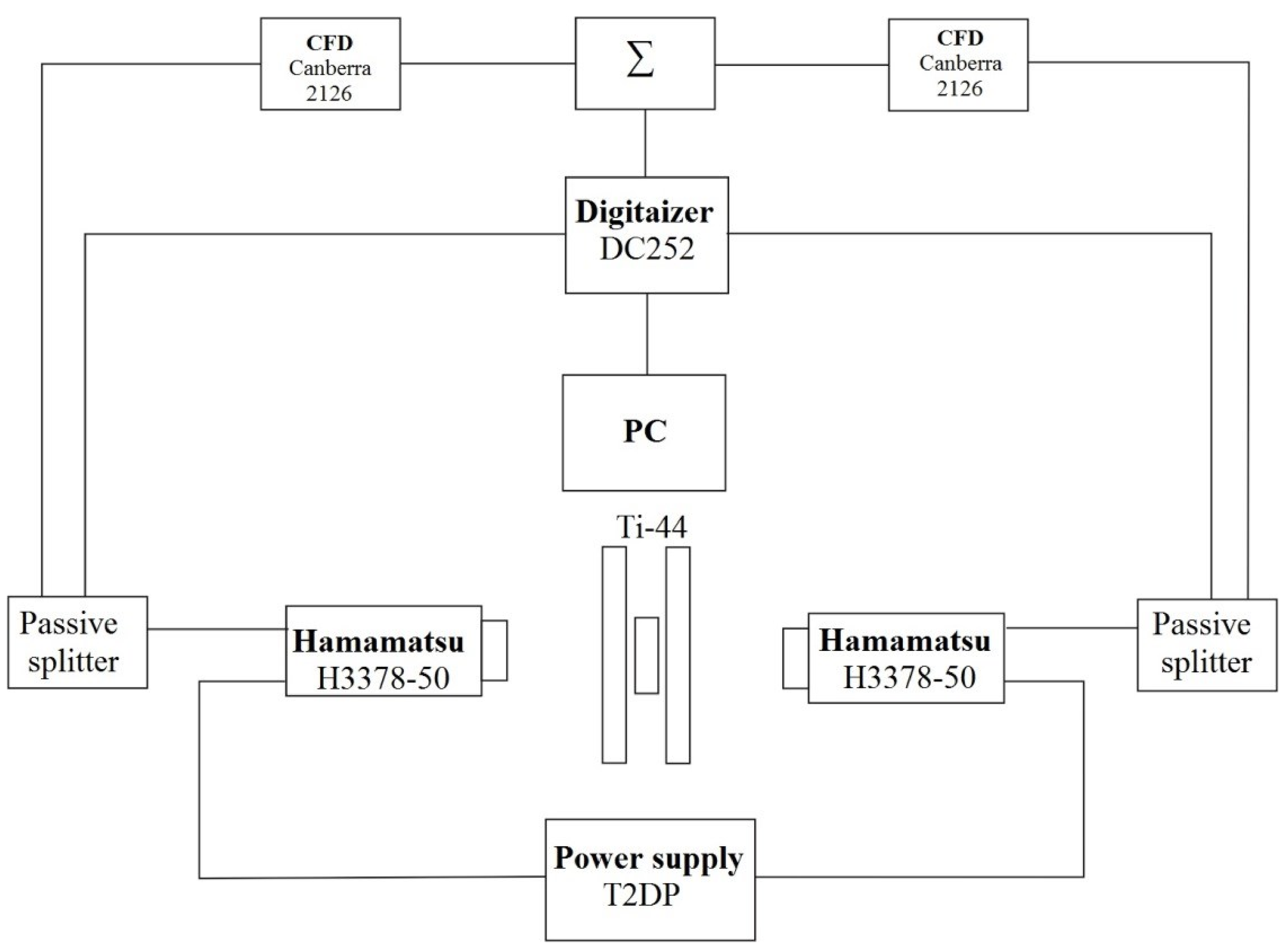
Introduction

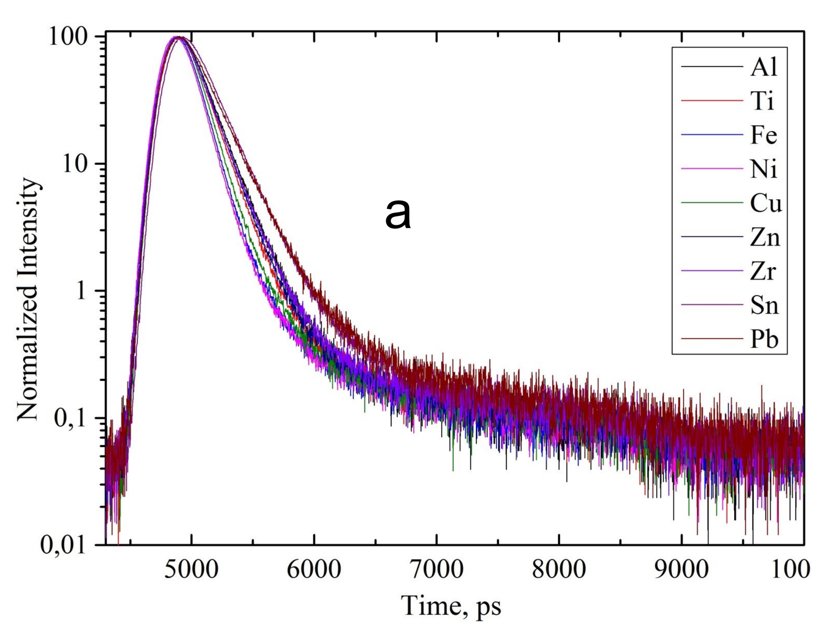
Positron spectroscopy (PS) methods are the most promising for controlling the defect structure of hydrogen containing systems due to high sensitivity and the ability to determine the type of defects and concentration. However, despite the potential capabilities of PS methods, their use is severely limited due to the low counting rate and the lack of techniques for decoding and interpreting the data, especially for metal-hydrogen systems.

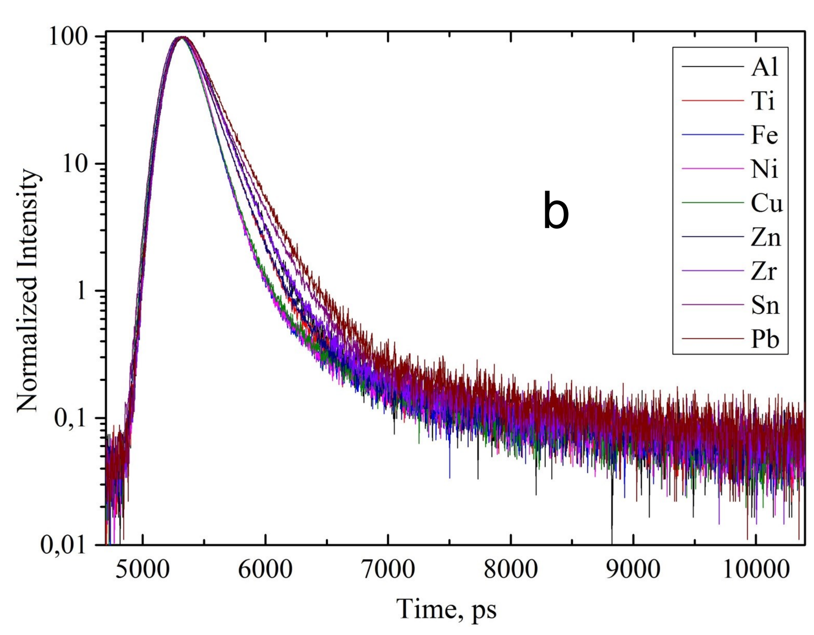
To study the evolution of the defect structure of metals and alloys upon hydrogen saturation, a completely digital spectrometric complex has been developed in which the methods of positron lifetime spectrometry and the coincidence analysis of the Doppler broadening of the annihilation line are integrated [1,2]. The main disadvantage of a fully digital spectrometric channel is the presence of a large number of background events in the spectrum, which significantly increases the size of the received file (up to 3 TB) and increases processing time (several tens of hours).

To eliminate this drawback, external synchronization systems are developed for each module. The external circuit carries out preliminary selection of signals and forms a control pulse, which then arrives at the trigger of the digitizer trigger. Thus, the digitizer performs further processing of only "useful" signals. The disadvantage of such systems is that additional devices (amplifiers, discriminators, coincidence circuit, etc.) that complicate the setup and operation of the spectrometer and also increase its cost are required for preliminary selection. The use of external synchronization systems reduces the rate of signal collection, but increases the efficiency of their processing. The use of analog devices in the digital spectrometric complex slightly increases the cost of the complex and makes it difficult to configure, but it allows to significantly improve its characteristics.

PALS module







Positron lifetime spectra in Retro (a) and Iretro (b) modes

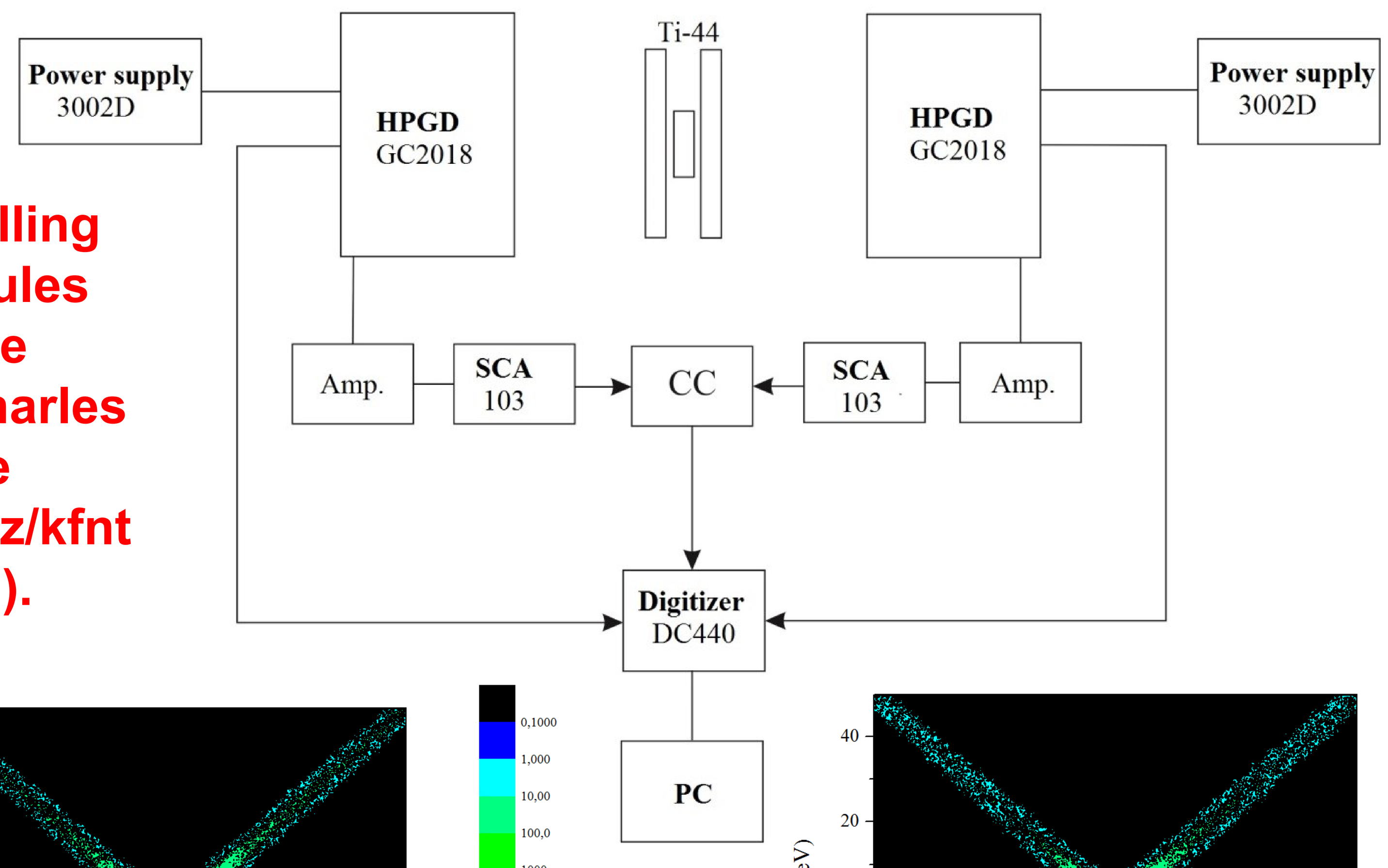
Source components: τ_1 = 149±1 ps (69,5 %), τ_2 = 302±1 ps (22,9 %), τ_3 = 1980±10 ps (7,6 %) and τ_1 = 149±1 ps (78,5 %), τ_2 = 427±1 ps (15,3 %), τ_3 = 2780±10 ps (6,2 %) for Retro and Iretro modes respectively.

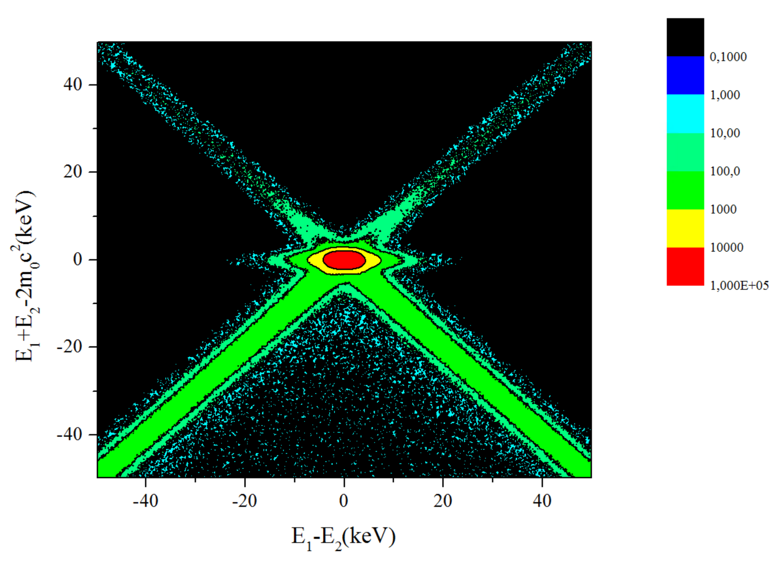
Z	Mode				Lifetime, ±1 ps [3]
	Retro		Iretro		
	$\tau_1 \pm 1$ ps	FWHM	$\tau_1 \pm 1$ ps	FWHM	
Al	163	179	163	172	165
Ti	149	162	147	165	150
Fe	106	159	107	167	111
Ni	103	163	102	177	109
Cu	115	172	116	167	120
Zn	148	175	149	172	153
Zr	163	164	163	158	164
Sn	196	181	199	168	200
Pb	208	172	208	177	204

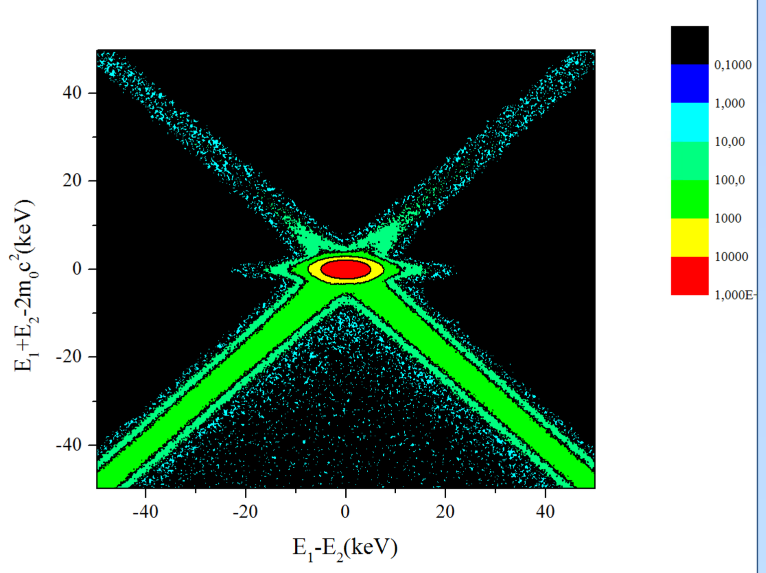
Average counting rate 90±30 counts/s

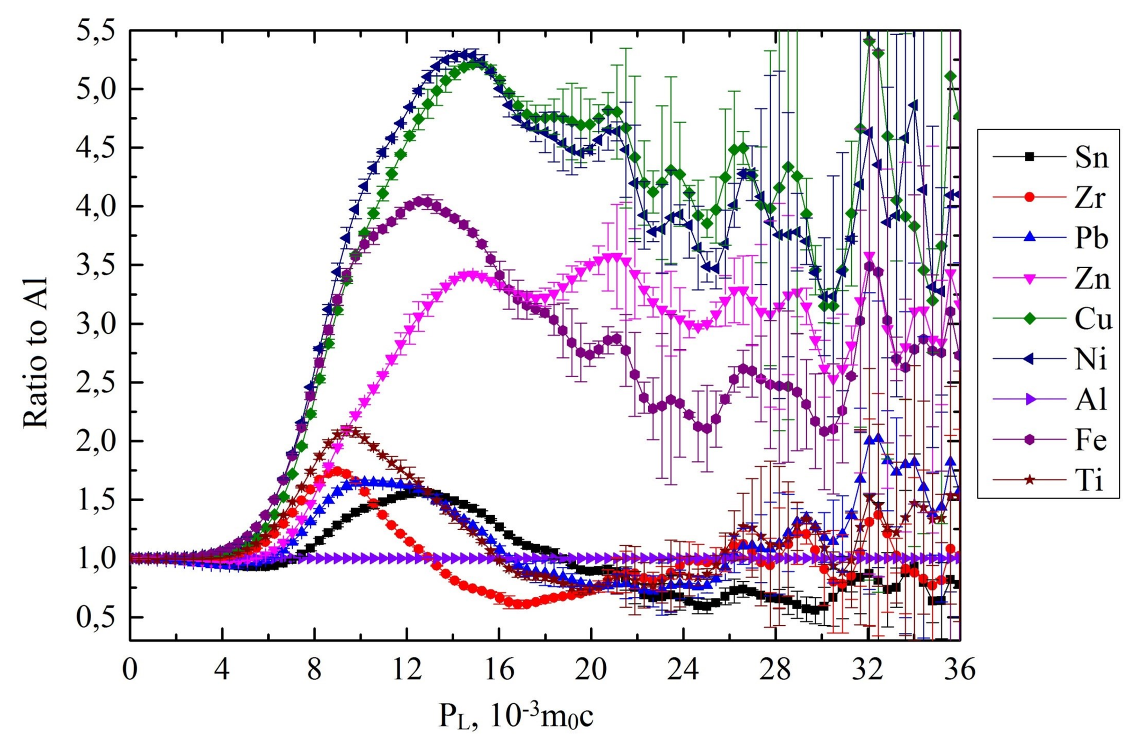
The software for controlling the spectrometric modules was developed by the Positron Group of the Charles University in Prague (http://physics.mff.cuni.cz/kfnt/pas/?page=software).

CDBS module









Ratio curves to Al for well-annealed materials

Materials	Z	Signal counting rate, (signals/s)	Spectrum Counting rate, (coinc./s)	FWHM, keV
Al	13	151	127	1,10
Ti	22	161	135	1,12
Fe	26	143	120	1,12
Ni	28	137	115	1,13
Cu	29	160	134	1,14
Zn	30	138	116	1,14
Zr	40	129	108	1,17
Sn	50	112	94	1,19
Pb	82	108	91	1,20

Conclusion

A semi-digital complex of positron spectroscopy with an external synchronization system based on the PALS and CDBS modules has the following technical characteristics using a positron source based on the ^{44}Ti isotope with the activity of 0.91 MBq:

- the time resolution of the digital lifetime module is 170 ± 7 ps, the counting rate (90 ± 30) s/s
- The energy resolution of the CDBS module is (1.16 ± 0.03) keV, the counting rate (116 ± 15) s/s.

References

[1] Bordulev Y. et al. Development of a digital spectrometric system for material studying by positron annihilation techniques //Strategic Technology (IFOST), 2012 7th International Forum on. – IEEE, 2012. – P. 1-4.

[2] Laptev R.S. et al. Gas-phase hydrogenation influence on defect behavior in titanium-based hydrogen-storage material //Progress in Natural Science: Materials International. – 2017. – Vol. 27. – №. 1. – P. 105-111.

[3] Robles J.M.C et al. Positron lifetime calculation for the elements of the periodic table //Journal of Physics: Condensed Matter. – 2007. – Vol. 19. – №. 17. – P. 176222.