SUPER-RADIANT LINAC-BASED THz SOURCES IN 2013

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Abstract

These proceedings shall give an overview over the rapidly growing number of super-radiant linac-based THz sources which have been developed and designed over the past 13 years following the seminal pilot experiment at the Jefferson lab energy recovery linac in 2001 [1]. More than 20 super-radiant THz facilities already exist or are planned worldwide and are listed together with a set of fundamental parameters in the appendix of this paper.

INTRODUCTION

Super-radiant THz sources are a relatively new class of accelerator-based photon sources. They became only technically feasible in the early 2000´s when accelerator technology had evolved to a stage where highly charged electron bunches could be compressed to the sub mm regime. A relativistic electron bunch prepared in that way allows generating coherent THz bursts during one single path through a radiator of synchrotron radiation. This generation principle leads to systematically different properties than that of the other already class of accelerator based coherent THz radiation namely that of the low gain THz free electron lasers (for details see [2] and references therein). In short, this corresponds to three key parameters which can be much more flexibly chosen in the design of these facilities: *(i) spectral bandwidth (ii) repetition rate (iii) carrier envelope phase stability*. In particular the latter property is of large importance in modern ultra-fast science experiments which aim at elucidating transient or magnetic field-driven dynamics (for timely review on such experiments see [3]). The particular interest of the ultra-fast community in super-radiant THz sources lies in their enormous scalability both in repetition rate and pulse energy. This stems from the fact that the conversion of electron energy into THz pulse energy can be done in the absence of any media. Recent trends as reported on the FEL13 conference were: firstly the emergence of many new facilities and facility proposals. Secondly, the development of new source concepts that go beyond the classical radiators such as coherent transition radiators, bending magnets or undulators and thirdly the combination of super-radiant THz sources with synchronized fs probes such as fs X-ray or fs laser pulses that allow elucidating dynamics on sub THz cycle timescales. A future challenge discussed on FEL13 is here the synchronization of such sources on sub THz cycle timescales. On approach which achieves few fs-level synchronization is shown in figure 1, where a super-radiant THz undulator pulse has been sampled sequentially by fs X-ray pulses [4]. In this case THz pulse and fs X-ray pulse are intrinsically synchronized because they are generated by the same electron bunch.

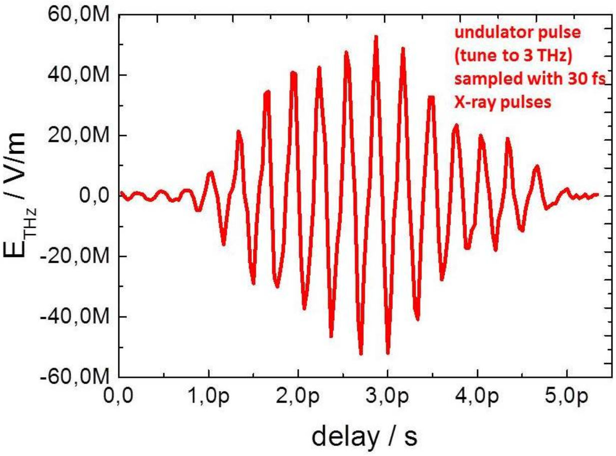

Figure 1: 3 THz pulse from the super-radiant THz undulator at FLASH sampled by the intrinsically synchronized fs X-ray pulses from the same electron bunch [4, 5].

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APPENDIX

Table 1: Super-radiant THz Facilities that are/have been Operational

Location (Name)	ν(THz)	source type	E(MeV)	(Micro)Pulse energy	Reprate	secondary source	publication
Tsukuba/ Japan (AIST-THz)	0.1–2	bending magnet, CTR	10 – 42	>100 nJ+	1-50 Hz (macro-pulsed)	fs laser	R. Kuroda et. al., Nucl. Instrum. Meth. A 637 (2011), S30.
Daresbury/ UK (ALICE)	0.1–0.5	bending magnet	25 (35)	< 70 nJ+	10Hz (macro-pulsed)	–	Y. Saveliev et al, Proceedings of IPAC10, Kyoto, TUPE096.
Stanford/ USA (FACET & LCLS - THz)	0.5 – 5 (FACET) 3 – 30 (LCLS)	CTR	20350 (FACET) 2600 – 20700 (LCLS)	>400 µJ+	10 (30)Hz (FACET) 120 Hz (LCLS)	fs laser OTR* fs-X-rays*?	A.Daranciang et. al., Appl. Phys. Lett. 99 (2011), 141117. Z. Wu et. al., Rev. Sci. Instr. 84 (2013), 022701.
Hamburg/ Germany (FLASH - THz)	0.1 - 30	CTR, undulator, bending magnet	400 – 1200	>100 µJ+	10 Hz (macro-pulsed)	fs laser(s) fs X-rays* OTR*	M. Gensch et. al., Infrared Phys. Technol. 51 (2008), 423. S. Casabuoni et. al., Phys. Rev. Spec. Top. 12 (2009), 030705. F. Tavella et. al., Nat. Photon. 3 (2011), 162.
Idaho/ USA (IAC-THz)	0.27–0.33	corrugated waveguide	5 (40)	25 nJ+	30 Hz (macro-pulsed)		A.Smirnov et.al., Proceedings of IPAC13, Shanghai, China, WEOWA080.
Newport News/ USA (Jlab - THz)	0.1 – 2	bending magnet	<150	0.1 µJ+	4.7MHz – 75MHz (quasi-cw)	OTR*	G.L. Carr et. al., Nature 420 (2001), 153.
Nihon/ Japan (LEBRA)	0.1 – 0.3	bending magnet	30 - 125	1 pJ+	<12.5 Hz (macro-pulsed)	IR FEL	FEL2013, New York, USA, TUPS066
Pohang/ Korea (PAL-THz)	0.3 – 3	CTR	75	>10 µJ+	10 Hz	fs laser	J. Park et. al., Rev. Sci. Instr. 82 (2011), 013305.
Brookhaven/ USA (SDL-BNL - THz)	0.1 - 1	CTR	200	400 µJ+	1 – 10 Hz	fs laser	Y. Shen et. al., Phys. Rev. Lett. 99 (2007), 043901.
Shanghai/ China (SINAP - THz)	0.3 – 0.8	undulator	14 - 30	2.42 µJ+	50 Hz (macro-pulsed)		J. Zhang et. al., Nucl. Instr. Meth. A 693 (2012), 23.
Frascati/ Italy (SPARC - THz)	0.1 - 5	CTR	120	>1 µJ+	10 Hz		E. Chiadroni et. al., Rev. Sci. Instr. 84 (2013), 022703.
Dresden/ Germany (TELBE)	0.1 - 3	CTR, CDR, undulator	< 40	1 µJ 100 µJ	< 13 MHz < 500 kHz	fs laser	M. Gensch et. al., in preparation (2013).

+ observed; *intrinsically synchronized

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Table 2: Super-radiant THz Facilities Which are Currently Under Construction or Proposed

Location (Name)	**ν(THz)**	**source type**	**E(MeV)**	**Pulse energy**	**Reprate**	**secondary source**	**Publication**
Hamburg/ Germany (FLASHII-THz)	1 – 30	CTR, undulator, bending magnet	400 – 1200	>100 µJ	10 Hz (macro-pulsed)	fs laser fs X-rays* OTR*	
Karslruhe/ Germany (FLUTE)	0.1 – 25	bending magnet, CTR	10 – 42	>100 µJ	1-50 Hz (macro-pulsed)	fs laser fs X-rays*	M. Nasse et. al., Rev. Sci. Instr. 84 (2013), 022705
Newport News/ USA (Jlab-THz)	0.1 – 5	undulator	150	1 µJ	4.7MHz – 75 MHz	UV*	S. Benson et al., Proceedings of IPAC12, New Orleans, USA (2012) TUPPP086
Daejeon/ South Korea (KAERI-THz)	0.1 – 10	undulator, multi-foil radiator	30	1 µJ	500 Hz	fs X-rays*	FEL2013, New York, USA, TUPS032, TUPS038
Lansing/ USA (Niowave-THz)	0.5 – 1.7	undulator	5	few nJ	350 MHz		FEL2013, New York, USA, TUPS011
Hsinschu/ Taiwan (NSRRC-THz)	0.1 – 10	bending magnet	30	?	10 Hz (macro-pulsed)		FEL2013, New York, USA, TUPS041
Triest/ Italy (TERAFERMI)	0.3 – 15	CTR	1200 –1500	50 µJ –1 mJ	10 – 50 Hz	fs laser	A.Perucci et. al., Rev. Sci. Instr. 84 (2013), 022702
Hamburg Germany (X-FEL - THz)	0.1 – 30	undulator, CTR	20000	>100 µJ	10 Hz (macro-pulsed)	fs laser fs X-rays	FEL2013, New York, USA, WEOBN004

*intrinsically synchronized