High power laser development in the UV for accelerators and light sources

Summary of PhD theses

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1. Introduction

Today research machines under development for high energy physical experiments are aiming towards the TeV range to explore the physics beyond the standard model. The Large Hadron Collider (LHC) synchrotron will extend this to the 14TeV and in parallel lepton-lepton colliders are being developed to perform the precision measurement on any newly discovered particles. As circular machines are limited by synchrotron radiation losses, Linear Accelerators (LINAC) are needed to reach these high energies. One of these large scale projects is the Compact Linear Collider (CLIC) at CERN running since the 1980's with the aim to create a high luminosity electron-positron collider at a few TeV centre of mass energy. CLIC is proposing a unique two beam acceleration scheme, whereby one high power beam (drive beam) produced at 12GHz by combining bunches at lower repetition rate is transferring its power into high gradient accelerating structures to accelerate a second beam (probe beam). CLIC Test Facility 3 (CTF3) is aimed at demonstrating this scheme.

At the same time Free Electron Lasers (FEL) are being developed around the world to produce high brightness photon beams at short wavelengths (X-UV) for condensed matter studies and ultrafast material science. FELs, based on LINACs and undulators, were making their way to shorter wavelengths and higher degree of coherence over the past decade and at the 1kV photon energy range they currently provide the brightest beams. However this requires extremely high quality short electron bunches to be produced, with ultralow emittance. Conventional lasers take their place here as part of a photo-injector (PI). PI is the electron source, where electron bunches are produced through photo-emission from a cathode irradiated by a laser and are accelerated to a few MeV by the field present in the gun. PI allows for approximately two orders of magnitude higher brightness, than conventional thermionic source and is also being considered for CLIC for both drive beam and probe beam injectors. Apart from the high particle beam quality achievable from these sources they also take advantage of the wide range of pulse length, repetition rates and pulse train structures, which can be generated with laser oscillators, amplifiers and optical gating systems. Lasers are essential part of a FEL facility not just by providing the primary electron source, but also by delivering ultrashort synchronized laser pulses for pump-probe measurements.

One of the ways to generate high intensity UV pulses is based on conventional (i.e. not FEL) multicolour laser systems, where the initial pulse production and amplification takes place in the infrared which is then converted to shorter wavelengths through non-linear processes. The development of Chirped Pulse Amplification (CPA) together with novel mode-locking techniques has provided a major step towards efficient amplification of ultrashort pulses in solid-state materials without optical damage or unwanted non-linear effects. CPA is taking advantage of dispersion of broad bandwidth pulses and amplifies stretched pulses to high fluence, but low intensity before recompressing them. Apart from amplifiers based on energy storage, optical parametric amplifiers are also used in these systems allowing for ultra broadband amplification. Each part of these complex laser systems could alter the quality of the laser beam and introduce losses in energy, bandwidth and stability, limiting the maximum focused intensity or the applicability of the laser.

2. Scientific objects and goals

In 2001 the photo-injector laser system at the CLIC Test Facility 2 (CTF2) at CERN was based on powerful flash-lamp pumped regenerative and multipass amplifiers and a pulse multiplication technique to produce a train of up to 48 pulses. With this scheme the scalability to produce longer pulse trains was impractical. Since many thousands of identical pulses are required in the UV to produce the high mean current electron beam for the final CLIC machine, it is necessary to develop the laser source futher to increase both mean power and average power. **My aim is to build a diode-pumped master oscillator power amplifier (MOPA) in multi-pass arrangement with 1047 nm seed light provided by a mode-locked Nd:YLF oscillator. I intend to test the steady-state properties of the system and to generate long trains of pulses at the 4th harmonic of the fundamental, satisfying CLIC Test Facility 2 requirements. I would also develop a code to calculate the predicted behaviour of the multipass amplifier, and compare the data with the measurements.**

The PILOT (Photo-injector Long Train) laser for CTF2 has performed well and apart from the stability specification all parameters were met. A test facility was created to build a photo-injector (PHIN), -including the laser system - with higher average electron beam current capability. For this system the laser amplitude stability requirements were very stringent at 0.25% rms level in the UV. **My aim was to design a 2 stage amplifier system for CTF3 with the same architecture as the PILOT laser and to check performance against the code. I would also test stability performance of the laser as well as perform correlation measurements between the laser and electron beams.**

One of the main challenges on CTF3 is to multiply the electron bunch rate up from 1.5 to 12 GHz. This is carried out using a delay loop and a combiner ring, with high frequency input and output switches to separate and “interleave” the electron bunches. With the current thermionic gun this, so called phase-coding, is achieved by sub-harmonic bunching, which is done over 8 consecutive electron bunches and causes considerable amount of unwanted satellites in the system. These satellites being at ~7% charge level can become a serious radiation hazard for the future CLIC machine as they propagate on a different path from the main electron beam. **My aim is to design and implement a phase-coding system directly on the laser, which provides a switch with a rise- and fall-time of <200ps at 140ns switching periods. Accurate phase-shift of the laser pulses by 180deg at each switch respect to the 1.5 GHz bunch rate is to be demonstrated. Furthermore, I intend to integrate the phase-coding into CTF3 PHIN photo-injector laser system and to test the performance with electron beam.**

To obtain UV light in efficient way, seed pulse generation and amplification takes place in the infrared and pulses are converted in non-linear crystals to UV. The probability of absorption of two photons in the same time is quadratically increasing with the intensity. This nonlinear absorption is called single beam two photon absorption (TPA). Although the phenomenon itself is well-known, the two-photon absorption coefficients of some practically important nonlinear crystals in the UV have not been available yet or the literature data is not consistent. **My aim is to determine the nonlinear absorption coefficient of the nonlinear crystals BBO, CLBO, LTB and KDP around 250 nm.**

Brightness has been mentioned before as the most important parameter, which is related to the focusability and the fluence of an ultrashort pulse. At the calculation of brightness/intensity one always assumes a certain pulse shape, typically Gaussian or $sech^2$. In realistic systems the temporal shape can be different from these, in some cases pre-or post-pulses can develop during stretching, amplification and compression. The temporal contrast, which is the intensity ratio of the pre- or post-pulses and the main pulse, is one of the most important parameters, as this can affect the interaction between the pulse and the material in the experiments. **My aim is to calculate the effect of real optical elements on the spectra and the phase and hence on the temporal contrast. Moreover, I make model calculations on what extent conventional diagnostics, such as spectrometer and auto-correlators, can be used to make estimations on the best achievable temporal contrast.**

3. Methods of investigation

During the photo-injector laser development I use several cw and mode-locked Nd:YLF oscillators, ranging up to 300mW output power with up to 1.5GHz mode-locked repetition rates. They provide the seed for the amplifiers I am assembling and testing. CCD cameras are used to measure pump homogeneity and output beam quality. Fast photo-diodes in conjunction with digital sampling oscilloscopes are used to measure gain building up over time as well as to resolve single pulses to monitor switching quality of the optical gates in the system. Femtochrome background free scanning intensity auto-correlator is used for pulse length measurement to verify gain narrowing and saturation effects. Power and energy meters from Gentec, Laser Probe and Coherent were providing the measurements for output power and conversion efficiency measurements. To study the thermal effects a radial shear Sagnac interferometer (home-built) is used, which is placed in the amplified beam and the recorded interferograms were analysed using a CCD frame store and software package Fringe Analyser (Oxford Frame store Applications Ltd.). The code to calculate predicted gain and steady-state is written in MathCad.

The two-photon absorption measurements are carried out on the KrF laser system in Szeged University. Homebuilt photo-diodes are calibrated to LaserProbe energy meter and sampled by and oscilloscope. I developed an automated LabView code to read and collect the data from the oscilloscope and analyse the results with a code written in MathCad. Beam profiles at high and low intensities are recorded with a CCD camera.

During the phase-coding development Hamamatsu streak camera is used to verify the fast switching, together with fast fiber coupled photo-diodes and sampling oscilloscopes. I designe an optical Cherenkov-line to measure the quality of the produced electron bunches, using ZEMAX. Gated, intensified cameras are used to monitor the electron beam shape through optical transition radiation and fast current transformer to measure the produced charge.

The contrast calculations were carried out with a MatLab code, using real data as well as typical scenarios for pulse shape or spectral shape distortions.

4. Results and discussion

1. I have designed and built a multi-pass diode-pumped MOPA for CERN CTF2, offering a combination of high gain and efficiency with high stability. A simple rod-cavity design and the establishment of quasi-steady-state operation resulted in a high gain saturated operation with mean output intensity during the pulse train of 7kW/cm^2 in the case of the Photo Injector Long Train (PILOT) laser for CTF2. I have developed a code to verify the operation of the amplifier and to provide a useful tool for further designs[J1.] . Zernike analysis of the measurements of pump distortion exhibited an almost pure astigmatic phase error from the thermal load showing, that Nd:YLF was indeed a good choice as an amplifier material, which can be compensated, up to high average power levels[J1]. PILOT system has allowed the first long train injector operation at CERN.

2. I have designed a two stage MOPA system for CTF3 with 9kW/cm^2 output mean intensity in the IR. Photo-injector laser[J2,C1-5] (PHIN) amplifiers exhibit an output stability of 0.2% rms and 0.34% rms, respectively, and proved the capability to compensate for the slow drifts of the input intensities. Response to fast variations of the input seed amplitude was investigated for the steady-state regime and time- and frequency domain measurements were carried out to study noise propagation through the system[J2,C6,] . The output pulse stability already competes favourably with that of the best already available lasers with active stabilization. This can be further improved using a more stable diode-laser power supply and improved coolant and room temperature stability, which was varying 5-6^{o}C over the day. Additional stabilisation is also achievable using a closed cycle feedback control system. Specified energy levels were delivered to the cathode. The CTF3 photo-injector driven by the PHIN laser, is still unique of its kind with its high average current capability[J3,C7-8]. The laser was also used to deliver photo-electrons for the Concept d'Accélérateur Linéaire pour Faisceau d'Electron Sonde (CALIFEs) probe beam injector, where the first two-beam acceleration experiments took place as a proof of principle for CLIC scheme[C9].

3. I have determined the two photon absorption coefficient of 5 mm - 15 mm long BBO, CLBO, KDP and LBO samples from the measurement of intensity dependent transmission at 248 nm[J4,C10-11]. The theoretical fit to the experimental results show a TPA value of 0.48 cm/GW, 0.5 cm/GW, 0.34 cm/GW, 0.22 cm/GW and 0.53 cm/GW for KDP, BBO (o-ray), BBO (e-ray), LTB and CLBO, respectively. To our best knowledge, this was the first measurement of the TPA coefficient of LTB and CLBO crystals, providing a good reference when choosing conversion or parametric amplifier crystals for high intensity applications in the UV regime.

4. I have designed and implemented a phase-coding system for the PHIN laser, which provides the required pulse structure for electron beam combination in CTF3 and for future CLIC application too[J5,C4,C12]. The system was based on fast Mach-Zehnder fiber modulators used in telecommunication. An accurate timing and amplitude balancing system was invented using frequency domain measurements. The delay can be set with 0.1ps accuracy and introduces no additional jitter to the laser oscillator. The amplitude balance between sub-trains have been set to be within the required error level of 0.1% rms. Further improvement is currently limited by fast noise of the laser oscillator. The performance of the system was verified also on the electron beam. Indeed, it showed a laser based switch free from satellites while all the important electron beam parameters have been preserved as charge, charge stability, energy spread, and emittance [J5].

5. I have developed a quick, reliable and universal method for estimation of the temporal contrast of high power pulses, which is especially useful in everyday laboratory practice. The calculation predicts, as was also proved in an experiment, that the best achievable temporal contrast of an ultrashort pulse can be estimated from the spectrum at a significantly lower dynamic range [J6],[C13-14]. Tolerances for the spectral transmission of the optics as well as for the non-compensated residual third order dispersion of a laser system have been established in order to obtain ultrashort pulses with high temporal contrast. As a result of the calculation I have also found, that Gaussian pulses are less sensitive to spectral clipping than $sech^2$ pulses and that more realistic soft spectral clipping allow for higher contrast, than hard cutting of the spectrum. I have also shown that conventional auto-correlators are not capable to estimate the contrast. I have shown, that double pulses within less than x10 of the laser pulselength will also be present in the spectrum through modulation. To confirm the modelling results, measurements have been carried out on the Titania Kr:F laser system as well as the LUND multi-TW laser system. There is a good agreement between the measured temporal shape and that one retrieved from the spectrum [J7].

4. Publications related to the theses

In refereed journals

J1. N. Ross**, M. Csatári,** S. Hutchins,
High performance diode pumped Nd: YLF amplifier
Appl. Opt., Vol. 42 (6), 1040-1047 (2003)

J2. M. Petrarca, M. Martyanov, **M. C. Divall,** G. Luchinin,
Study of the Powerful Nd:YLF Laser Amplifiers for the CTF3 Photoinjectors
J. Quant. Elec., Vol 47 (3) 306-313 (2011)

J3. Eric Chevallay**, Marta Csatari,** Anne Dabrowski, Steffen Doebert, Daniel Egger, Valentine Fedosseev, Oznur Mete, Maja Olvegaard, Massimo Petrarca
Production of long bunch trains with 4.5µC total charge using PHIN photo-injector
Phys. Rev. Lett. STAB (accepted)

J4. **M. Divall,** K. Osvay, G. Kurdi, E.J. Divall, J. Klebniczki, J. Bohus, Á. Péter and K. Polgár
Two-photon-absorption of frequency converter crystals at 248 nm
Appl. Phys. B: Lasers and Optics Vol. 81, 8 (2005)

J5. **M. 'Csatari' Divall,** A. Andersson, B. Bolzon, E. Bravin, E. Chevallay, S. Döbert, A. Drozdy, V. Fedosseev, C. Hessler, T. Lefevre, S. Livesley, R. Losito, Ö. Mete, M. Petrarca, A.N. Rabiller
Fast phase switching within the bunch train of the PHIN photo-injector at CERN using fiber-optic modulators on the drive laser
Nucl. Instr. and Meth. in Physics Research Section A Vol. 659, 1, p. 1-8 (2011)

J6. K.Osvay, **M.Csatári,** A.Gaál, I.N.Ross
Temporal contrast of high intensity femtosecond UV pulses
J.Chin.Chem.Soc. 47 855-857 (2000)

J7. K. Osvay, **M. Csatari,** I. N. Ross, A. Persson and C.G. Wahlstr¨om
On the temporal contrast of high intensity femtosecond laser pulses
Laser and Particle Beams Vol. 23 p. 327-332, (2005)

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C1. Petrarca, M., Fedosseev, V., Elsener, K., Lebas, N., Losito, R., Masi, A., **Divall, M**., Hirst, G., Ross, I., Vicario, C., Boscolo, I., Cialdi, S., Cipriani, D.
CTF3 photo-injector laser
Lasers and Electro-Optics Europe, 2009, CLEO/Europe IBSN 978-1-55752-869-8 (2009) *poster*

C2. G. Kurdi, I. O. Musgrave, **M. Divall,** E. Springate, G. Hirst, I. Ross, W. Martin:
High Average Power Phase-Coded Laser System for the CTF3 Photoinjector
Conf. on Lasers and Electro-Optics, 2007, Baltimore, USA, paper CWD5 (2007) *poster*

C3. R. Losito, H.-H. Braun, N. Champault, E. Chevallay, V. Fedosseev, A. Kumar, A. Masi, G. Suberlucq ,**M. Divall,** G. Hirst, G. Kurdi, W. Martin, I. Musgrave, I. Ross, E. Springate, G. Bienvenu, B. Mercier, C. Prevost, R. Roux
The PHIN photoinjector for the CTF3 drive beam
Proceedings of EPAC 2006, Edinburgh, Scotland WEPLS059 p. 2517 (2006) *poster*

C4. G. Kurdi, I.O. Musgrave**, M. Divall,** E. Springate, G. Hirst, I. Ross and W.E. Martin
High Average Power Phase-Coded Laser System for the CTF3 Photoinjector.
OSA 1-55752-834-9 (2005)

C5. **M. Divall,** E. Springate, G. Hirst, I. Ross, G. Suberlucq, R. Losito,
A diode-pumped laser system for the photo-injector of an accelerator
Lasers and Electro-Optics Europe, 2005. CLEO/Europe. CA8-6-TUE (2005) *oral*

C6. **Marta 'Csatari' Divall**, Eric Chevallay, Valentine Fedosseev, Nathalie Lebas, Roberto Losito, Massimo Petrarca, Mikhail A. Martyanov, Vladimir V. Lozhkarev, Grigoriy A. Luchining
Stability of a high power diode-pumped Nd:YLF laser system for photo-injector applications at CERN
SPIE, Photonics Europe 2010 7721-33 (2010) *oral*

C7. M. Petrarca, H.-H. Braun, E. Chevallay, S. Doebert, K. Elsener, V. Fedosseev, G. Geschonke, R. Losito, A. Masi, O. Mete, L. Rinolfi, A. Dabrowski, **M. Divall**, N. Champault, G. Bienvenu, M. Jore, B. M. Mercier, C. Prevost, R. Roux, C. Vicario
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Proceedings of PAC09, Vancouver, BC, Canada MO6RFP063 p. 509-511 (2009) *poster*

C8. M. Petrarca, E. Chevallay, S. Doebert, A. Dabrowski, **M. Divall,** V. Fedosseev, N. Lebas, T. Lefevre, R. Losito, D. Egger, O. Mete
Performance of the PHIN high charge photo injector
THPEC032 Proceedings of IPAC'10, Kyoto, Japan p. 4122 (2010) *poster*

C9. W. Farabolini, D. Bogard, A. Curtoni, P. Girardot, F. Peauger, C.S. Simon, E. Chevallay, **M. Divall Csatari,** N. Lebas, M. Petrarca, A. Palaia, R.J.M.Y. Ruber, V.G. Ziemann
CTF3 Probe Beam LINAC Commissioning and Operations
IPAC 2011 MOP001 (2011) *oral*

C10. **M.Csatári,** K.Osvay, J.Klebniczki, G.Kurdi, E.J.Divall, J.Bohus, Á.Péter
Two-photon-absorption of frequency upconverter crystals at 248 nm
28th ECLIM, Rome, Italy, 2004, paper Mo/P/21 (2004) *poster*

C11. **M. Csatári,** K. Osvay, J. Klebniczki, G. Kurdi, E.J. Divall
Two-photon absorption measurements in frequency converter crystals for ultraviolet pulses
FemtoMat 2002, Visegrád, Hungary, (2002) *oral*

C12. **M. Divall Csatari,** A. Andersson, B. Bolzon, E. Bravin, E. Chevallay, A.E. Dabrowski, S. Döbert, V. Fedosseev, C. Heßler, T. Lefèvre, S. Livesley, R. Losito, O. Mete, M. Olvegård, M. Petrarca, A. Rabiller, Drozdy, D. Egger

High Charge PHIN Photo Injector at CERN with Fast Phase Switching within the Bunch Train for Beam Combination
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C13. K.Osvay, **M.Csatári,** I.N.Ross, A.Persson, C.-G.Wahlström
On the temporal contrast of high intensity fs laser pulses
28th ECLIM, Rome, Italy, 2004, paper We/O2/4/O (2004) *poster*

C14. K. Osvay, **M. Csatári,** I.N. Ross, A. Persson, C.-G. Wahlström
On the temporal contrast of high intensity fs laser pulses
2nd FemtoMat Conference, Bad Kleinkirchheim, Austria, 2004, paper We 2. (2004) *poster*

5. Other publications

In refereed journals

J8. G. Kurdi, K. Osvay, **M. Csatári,** I. N. Ross, J. Klebniczki
Optical parametric amplification of femtosecond ultraviolet laser pulses
IEEE J.Sel.Top.Quant.Electr. 10 (2004) (invited)

J9. K. Osvay, A. P. Kovács, Z. Heiner, G. Kurdi, J. Klebniczki, **M. Csatári**
Angular dispersion and temporal change of femtosecond pulses from misaligned pulse compressors
IEEE J.Sel.Top.Quant.Electr. 10 (2004) 213-220

J10. K.Osvay, G.Kurdi, J.Klebniczki, **M.Csatári,** I.N.Ross
Demonstration of high gain amplification of femtosecond UV laser pulses
Appl. Phys. Lett. 80 (2002) 1704-1706

J11. K.Osvay, G.Kurdi, J.Klebniczki**, M.Csatari,** I.N.Ross, E.J.Divall, C.H.J.Hooker, A.J.Langley
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J12. I.Képíró, K. Osvay, **M.Divall**
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Appl.Surf.Sci. **253** (2007) 7798-7805

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C15. K.Osvay, A.P.Kovács, Z.Heiner, **M.Csatári**, Z.Bor, G.Kurdi, M.Görbe, J.Klebniczki, I.E.Ferincz:
A table-top high contrast TW laser system
CLEO/Europe, EQEC Focus Meeting, 2005, Münich, Germany, paper CG-13-TUE (2005)

C16. G. Kurdi, K. Osvay, Z. Bor, I. E. Ferincz, J. Hebling, J. Klebniczki, A. P. Kovács, I. N. Ross, R. Szipõcs, **M. Csatári,** K. Varjú:
A TW laser system with controllable chirp and tuneable UV pulses
Recent Advances in Ultrafast Spectroscopy (Proc. of UPS 2001) Leo S. Olschki, Firenze, p.249-256 (2003)

C17. K. Osvay, G. Kurdi, A. P. Kovács, Zs. Heiner, **M. Csatári,** J. Klebniczki, I. E. Ferincz
Measurement of residual angular dispersion and temporal lengthening of femtosecond pulses due to misalignment of pulse compressors
Ultrafast Optics IV, Vienna, (2003)

C18. P. Kovács, K. Varjú, G. Kurdi, K. Osvay, Zs. Heiner, J. Klebniczki, **M. Csatári**
Experimental investigation of angular dispersion in ultrashort pulses having Gaussian spatial profile
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C19. K. Osvay, G. Kurdi, J. Klebniczki, **M. Csatári,** I.N. Ross
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Theory and experiment in ultrafast processes, European Science Foundation ULTRA Programme, Vilamoura, Portugal, PP16, 53-54 (2002)

C20. K.Osvay, G.Kurdi, J.Klebniczki, **M.Csatari**, I.N.Ross
High gain amplification of femtosecond UV laser pulses
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C21. K. Osvay, G. Kurdi, J. Klebniczki, **M. Csatári,** I. N. Ross
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Noncollinear optical parametric amplification of femtosecond UV pulses
CLEO/Europe-EQEC Focus Meeting 2001, Munich, Germany, C-PSL 158 (2001)

TÁRSSZERZŐI NYILATKOZAT

Alulírott Dr. Bohus János, Drozdy András, Gaál Attila, Dr. Klebniczki József, Dr. Kurdi Gábor, Dr. Osvay Károly, Dr. Péter Ágnes, Dr. Polgár Katalin hozzájárulunk, hogy Divall 'Csatári' Márta felhasználja:

- K. Osvay, **M. Csatari,** I. N. Ross, A. Persson and C.G. Wahlstr¨om , *On the temporal contrast of high intensity femtosecond laser pulses*"
  Laser and Particle Beams Vol. 23 p. 327-332, (2000)
- K.Osvay, **M.Csatári**, A.Gaál, I.N.Ross *Temporal contrast of high intensity femtosecond UV pulses*
  J.Chin.Chem.Soc. Vol. 47 p. 855-857 (2000)
- **M. Divall**, K. Osvay, G. Kurdi, E.J. Divall, J. Klebniczki, J. Bohus, Á. Péter and K. Polgár *Two-photon-absorption of frequency converter crystals at 248 nm*
  Appl. Phys. B: Lasers and Optics Vol. 81, p. 8 (2005)
- **'Csatari' Divall, M.**, Andersson, A., Bolzon, B., Bravin, E., Chevallay, E., Döbert, S., Drozdy, A., Fedosseev, V., Hessler, C., Lefevre, T., Livesley, S., Losito, R., Mete, Ö., Petrarca, M., Rabiller, A. N. *Fast phase switching within the bunch train of the PHIN photo-injector at CERN using fiber-optic modulators on the drive laser*
  Nuclear Instruments and Methods in Physics Research A, Vol. 659, 1, p. 1-8. (2011)
- **M. Csatari Divall,** A. Andersson, B. Bolzon, E. Bravin, E. Chevallay, A. Dabrowski, S. Doebert, A.Drozdy, V. Fedosseev, C. Hessler, T. Lefevre, S. Livesley, R. Losito, M. Olvegaard, M. Petrarca, A.N. Rabiller, D. Egger, O. Mete *High charge PHIN photo-injector at CERN with fast phase-switching within the bunch train for beam combination*
  MOPC150 Proceedings of IPAC2011, San Sebastián, Spain (2011)

közös közleményünkben foglalt eredményeinket a Szegedi Tudományegyetem Fizika Doktori Iskola keretében a PhD fokozat eléréséért benyújtott dolgozatában, és egyúttal kijelentjük, hogy ezeket az eredményeket nem használtuk fel tudományos fokozatunk megszerzésekor, s ezt a jövőben sem fogjuk tenni. A szóban forgó közleményben a jelölt szerepe meghatározó fontosságú.

Szeged, 2012. január 12.

.... Divall 'Csatári' Márta	.... Drozdy András
.... Dr. Bohus János	.... Gaál Attila
.... Dr. Klebniczki József	.... Dr. Kurdi Gábor
.... Dr. Péter Ágnes	.... Dr. Osvay Károly
	.... Dr. Polgár Katalin