Summary of the LTECNC sessions of the first ELAN workshop

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Abstract

This summary gives a brief report of the presentations and discussions which took place in the various sessions of the work-package LTECNC (see the list given at the end). They focus on subjects related to R&D associated with normal conducting linear colliders and accelerators and were related whenever relevant to the existing infrastructure still under extension at CERN, namely the CLIC test facility CTF3. The subjects dealt with can essentially be grouped into five area, which are CTF3 and the two-beam scheme, electron sources and photo-injectors, accelerating structure and the two-beam acceleration, pre-alignment and vibration stabilization, as well as RF deflectors. Photo-injector topic is closely linked to the PHIN Joint Research Activities which will also be reported in a separate document. Talks specific to the work-package ANAD (new techniques of acceleration) and given in a common session with LTECNC are mentioned here, but are actually reported in the ANAD summary.

1. CTF3 facility and two-beam scheme R&D.

An overview was given of the necessary R&D and especially of the CLIC test facility CTF3 which is presently under construction for demonstrating the key issues related to the CLIC technology and to the two-beam scheme (CARE/ELAN Note-2004-xx6). The main challenges were recalled, distinguishing between those common to all multi-TeV linear colliders (high accelerating gradient, generation and preservation of ultra-low emittance beams, beam-delivery and interaction-point issues, and physics with collisions in high beamstrahlung regime) and the challenges specific to the CLIC technology (30 GHz components with manageable wake-fields, efficient RF power production with two-beam technology and operability of intense beams).

The conclusion of the Technical Review Committee was recalled, i.e. the list of the key-issues related to the CLIC technology concerning the feasibility (test of nominal damped accelerating structure, validation of drive beam generation, fully loaded linac operation, design of an ON/OFF power extraction structure) and the design finalization (validation of drive-beam stability and losses, design of machine protection system, test of relevant linac sub-unit with beam, validation of Multi-Beam Klystron with long RF pulse). Two more topics are valid for any multi-TeV Collider, the effects of coherent synchrotron radiation in bunch compressors and the design of an extraction line.

The CLIC test facility CTF3 is being built to demonstrate all these key-issues of the two-beam scheme. Issues common to all linear colliders, like the generation of very small emittances in the damping ring, the low-emittance transport, the instrumentation and the reliability, are planned to be treated in collaboration with European Laboratories within the Design Study proposed in FP6 and which should be closely linked to ELAN.

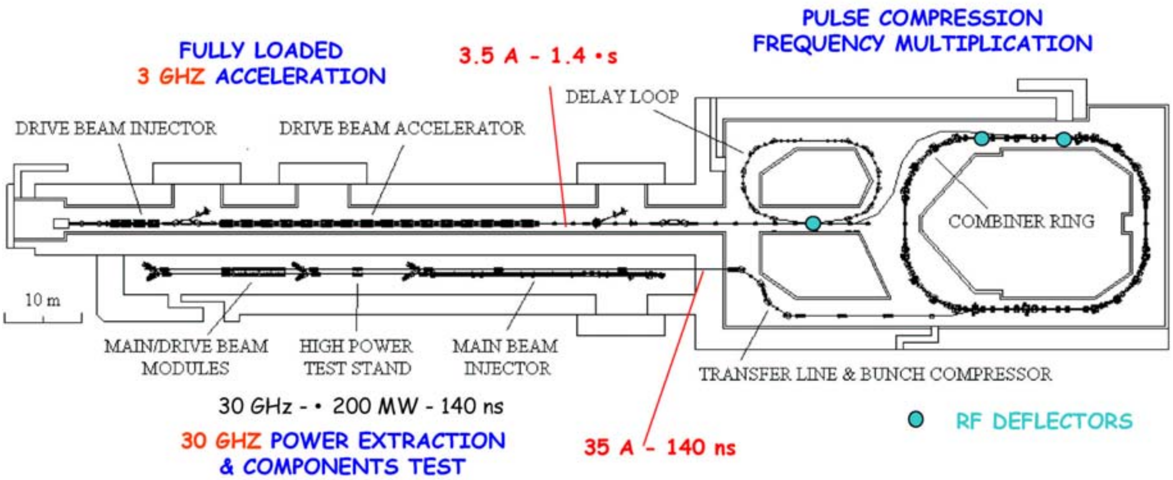

Fig.1 Scaled Layout of the test facility CTF3

Basic designs of CLIC sub-systems have been made but more design work is still required. The technical feasibility topics related to the two-beam scheme have been addressed to a point in the CLIC test facility CTF2 and will be dealt with in the CTF3 under construction. The most important achievements are:
-- In the CTF2 test, the energy of a single electron bunch was increased by 60 MeV using a string of 30 GHz accelerating cavities powered by a high intensity drive linac.
-- Gradients of 150 and 190 MV/m have been obtained in CTF2 using respectively tungsten and molybdenum-irises in 30 GHz copper structures with pulse lengths of 16 ns.
-- A demonstration of the principle of the bunch combination scheme has been made at low charge, using a modified layout of the former LEP Pre-Injector (LPI) complex.
-- A full-beam-loading operation has been achieved experimentally, using the injector of the new CLIC Test Facility 3 (CTF3).
-- A prototype CLIC quadrupole has been stabilized to 0.9 ±0.1 nm horizontally and 0.4 ± 0.1 nm vertically using state-of-the-art stabilization equipment. Sub-nm stability is required to collide nm-size beams.

The CLIC collaboration wishes the involvement of new potential participants in the R&D work under way on a two-beam scheme opening the path towards a multi-TeV linear collider. The work packages proposed to those interested are shortly listed here:1) combiner ring with transfer lines and bunch compressor, 2) 30 Ghz power test stand, 3) CLIC experimental area, 4) 200 MeV probe beam linac, 5) CLIC linac sub-unit with beam, 6) 35 A test beam line, 7) 30 Ghz structure development, 8) CTF3 operation, 9) 30 Ghz stand alone power source. Other topics which retained interest for ELAN are the application of the RF deflectors, the studies in CTF3 of Coherent Synchrotron Radiation with variable bunch length, the design of the bunch compressor after beam recombination and the use of CTF3 as test bench for diagnostics and final focus.

The schedule in mind for the multi-TeV linear collider R&D is that the feasibility be demonstrated and the design finalized before 2010.

2. Electron sources and photoinjectors

The JRA PHIN on the photoinjectors is part of the CARE project and closely linked to the workpackage LTECNC of ELAN. Its objective is to perform R&D on charge-production by interaction of laser pulse with material within RF field and improve or extend the existing infrastructures in order to fulfil the objectives, as well as to coordinate the efforts done at various Institutes on photoinjectors. The goal is to produce an electron source with brightness unachievable with conventional thermoionic gun. The PHIN activities successfully started and were reviewed in a PHIN meeting which was run parallel to the ELAN workshop by the External Review Committee. PHIN status will be subject of a separated report by the PHIN team.

The design layout of a superconducting RF photo-injector, the parameters of the superconducting cavity and the expected electron beam parameters were presented (FZR Rosssendorf). The SRF gun will have a 3½-cell niobium cavity working at 1.3 GHz and 2 K. Most of the component designs are finished, with three cavities in fabrication, the cathode cooling system and the preparation chamber in construction. The design of the normal conducting RF photo-injector for CTF3 is finished (LAL Orsay). Beam dynamics (gun performance), beam loading and vacuum mechanics (in situ baking) have been studied. A prototype will be ordered before summer and tested until September 2004. Status of both the photo-guns is summarized in companion notes (CARE/ELAN Note-2004-xx7 and CARE/ELAN Note-2004-xx8).

The Eindhoven programme on a high brightness electron source is aiming at a source suitable for laser wake-field experiment, producing a very short pulse (75-100 fs) of modest charge (10-100 pC) at an energy of 10 MeV for an emittance of 1 mm·mrad. The use of this source (photo-gun followed by an S-band RF booster) in accelerators seems limited, because of the intrinsic charge limitation related to the short bunch-length.

ELAN is interested by the photo-injector work; in particular, by the applications of high brightness and high-charge beam production, the limits of the PHIN technology for very short bunches, the possible application of SC gun (CW mode), the production of very short bunches and the all-optical generation of electron bunches (laser and plasma).

3. Accelerating Structure development and two-beam acceleration.

Main-linac accelerating structures and drive-linac decelerating (transfer) structures are being developed in the CLIC study (CERN/CLIC Note 593). Both types of structures have extremely demanding high-gradient, high-power and wake-field performance requirements. Extensive theoretical, computational and experimental studies have been necessary to progress towards their realization. The challenge of the transfer structures is to extract RF power keeping the impedance and the effects on the beam low. For the accelerating structures, the goal is to achieve a high gradient while keeping under control the wake-fields, the risks of RF breakdowns and of fatigue. With this in view, a new accelerating structure design, HDS (Hybrid Damped Structure), with improved high-gradient performance, efficiency and simplicity of fabrication has been designed. An optimization of the structure with an accelerating gradient of 150 MV/m at 30 GHz results in 29 % rf-to-beam efficiency. This optimization keeps the surface field for the Mo-irises below 378 MV/m and the pulsed surface heating below 56 K. The fatigue after the required $5\ 10^{10}$ cycles is reduced by using CuZr alloy and the HOM are absorbed in the HDS structures by 4 additional slots in the damping wave-guides. The ratio of the surface field to the accelerating field is 2.2 for a Q of 3900. The wake-field at the level of the second bunch is reduced by a factor about 100. Prototyping and testing have to be done.

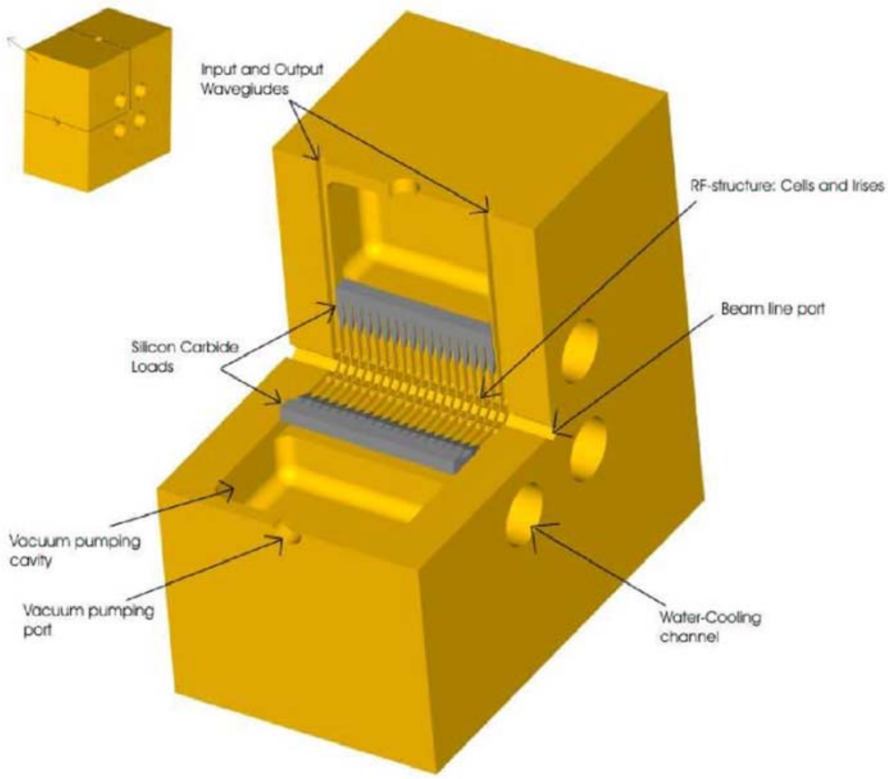

Fig. 2 Schematic geometry of the HDS structure

A different approach (TU Berlin) for NC structures was discussed. Millimeter-wave planar accelerating structures are indeed well suited for fabrication by deep x-ray lithography. In a first step, a 30GHz constant impedance structure was designed, built and tested under high power at CTF2. Gradients of around 50MV/m were achieved at pulse lengths of 15ns. Next, a very strong suppression of transverse wake-fields were attempted. It turned out that damping waveguides are needed in every cell. Solutions for a suppression by a factor of 100 within less than 1ns (20cm or second bunch location) were found. The ratio of the surface field to the accelerating field however reached a factor as high as 4 to 6 and even with an optimized geometry this factor will not go below 3, which represents a severe limitation of this solution (CARE/ELAN Note-2004-xx9).

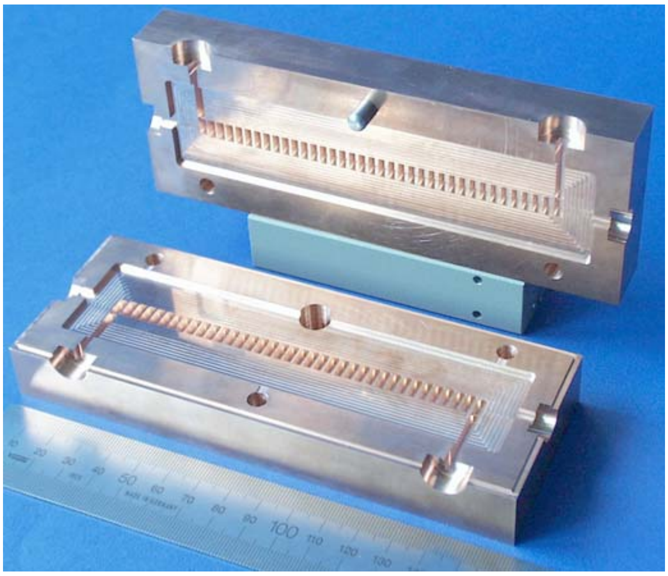

Fig. 3 Interior view of a planar stucture

An older idea (TU Berlin) of a short pulse two-beam accelerator with energy recuperation was presented for discussion, in view of the gradient limit at longer RF pulses. It is a system where the cavities for the drive and main beams are directly coupled such that a beating process takes place with a shift of the field envelopes resulting in the acceleration of the main beam. At 30 GHz and with an inter-cavity coupling of 3% an RF pulse of 1ns is possible. Although the device is essentially a single bunch machine, an energy recuperation scheme is easily incorporated which brings the overall efficiency in the range of about 10 % (CARE/ELAN Note-2004-x10).

4. Pre-alignment and vibration stabilization

The Oxford Linear Collider Alignment and Survey (LiCAS) group together with the DESY applied geodesy group address the question of alignment and survey of a linear collider. They develop a "Rapid Tunnel Reference Surveyor" (RTRS) to make automated surveys of a reference network and, in a later stage, of the accelerator components. The LiCAS group also works on two optical metrology systems for the RTRS: the Frequency Scanning Interferometry (FSI) and the Laser Straightness Monitor (LSM). FSI is an "optical ruler" capable of measuring distances of several metres to a precision of approximately 1 micron. A network of FSI interferometers is used to measure the 3D position of reference markers in the tunnel wall to a precision of a few microns. The LSM measures the transverse displacement and rotations of an object with respect to a laser beam that runs through the RTRS in an evacuated pipe. The combination of these two techniques should overcome the limitations of traditional open-air survey techniques that mainly result from refraction in the tunnel air. The expected pre-alignment precision of the system is 200 µm over 600 m. It however seems possible to increase the achievable accuracy and ELAN sees interest in studies aiming at the precision of the order of 10 µm needed in a multi-TeV linear collider.

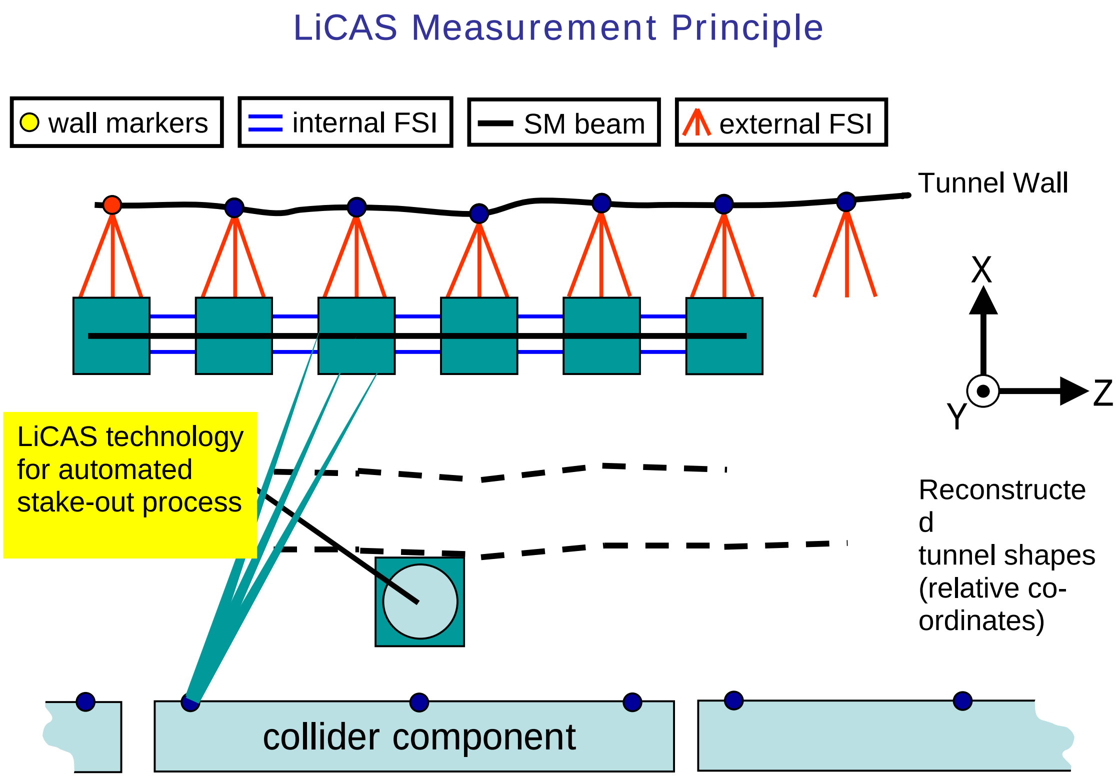

Fig. 4 Linear Collider Alignment and Survey

CLIC aims at spot sizes of 55nm (horizontal) times 0.7nm (vertical) for e^+e^- collisions at 3 TeV; at lower energies NLC aims at 60 nm x 0.7 nm and TESLA at 553 nm x 5 nm. Strict stability tolerances must be respected in order to achieve a sufficient overlap of the two colliding beams. A stability test stand has been set up at CERN, bringing latest stabilization technology to the accelerator field (CERN/CLIC Note 562). Using commercially available devices with active piezoelectric feet, a CLIC prototype magnet was stabilized in a normal working environment to 0.4-nm vertical and 0.8 nm horizontal RMS motion above 4 Hz (from about 4 to 6 nm on the ground). The results approach the requirements for CLIC which are 1.3 nm (V) uncorrelated in the linac above 4 Hz and 0.2 nm (V) in the final focus above 15 Hz. Vibration spectra and dependence on the flow of cooling water were measured. Simulation studies predict that such a stabilization system might maintain 70 % steady luminosity. Design of supports remain to be done still as well as checking if performance is maintained in the normal conducting case. In superconducting case, piezoelectric feet work in principle and a study should be performed.

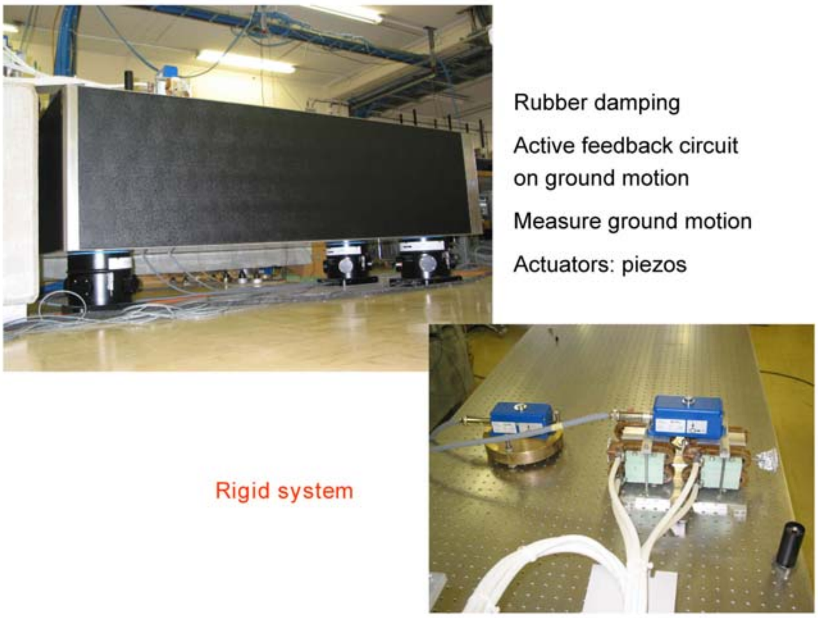

Fig. 5 CLIC vibration test stand

The stabilization study will be pursued in the LAPP/ESIA group which started to work on finite-element simulations of the final focus stabilization and to make vibration measurements on the recently installed test bench. The planned activities concern feedback loops and simulation of stabilization loops, mechanical simulations for the final focus quadrupoles (3.5 m long object of small diameter), the calculation of the intrinsic modes, the validation of the feedback loop with mock-up and the characterization of the ground motion in the LAPP site area with adapted sensors and actuators (CARE/ELAN Note-2004-005).

LTECNC encourages the collaboration between the various ELAN participants interested in this kind of stabilization studies (mainly CERN, DESY, LAPP). A. Jeremie from LAPP (Annecy) accepted to coordinate the ELAN efforts in this field.

5. RF Deflectors for Combiner and Damping Rings

Study and design of RF deflectors for the CTF3/CLIC Combiner Ring and Delay Loop and for the TESLA Damping Ring have been done (CARE/ELAN Preprint-2004-xx1). A couple of such RF deflectors have been constructed and tested in CTF3. Important issues are the electromagnetic characteristics of both standing and traveling wave structures, the beam dynamics in the combiner ring and in the delay loop and the beam loading effects in the deflectors. Concerning the TESLA damping ring, different injection/extraction schemes with 2, 4 or 6 RF deflector groups fed at 2 or 3 different RF frequencies, are considered. TESLA damping ring deflection system is similar to the CTF combiner ring deflector in principle.

LTECNC expects the synergy between the two design works to be actively pursued. F.Marcellini will naturally coordinate the efforts in this direction.

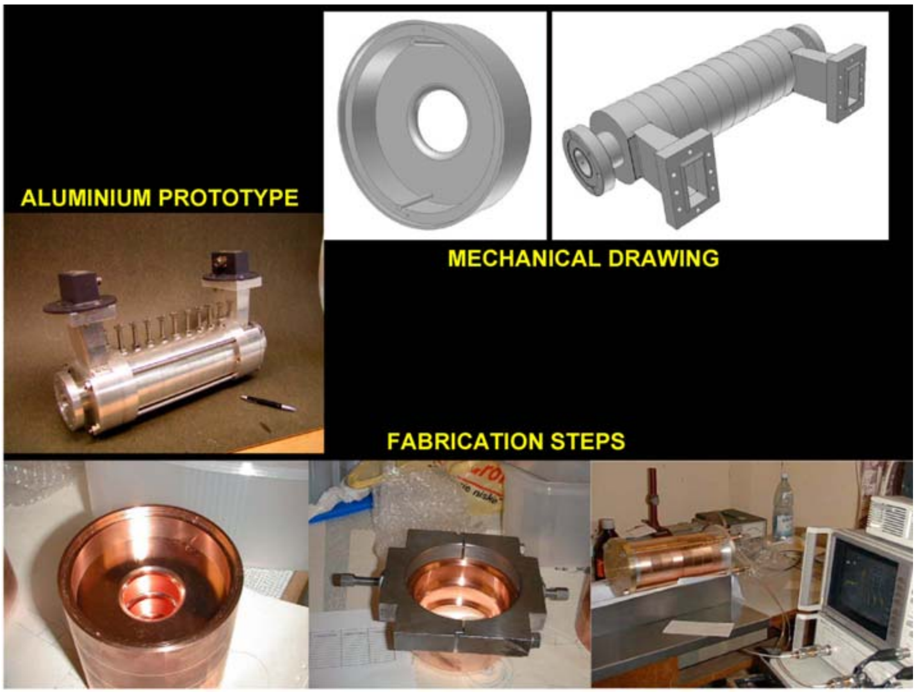

Fig. 6 Prototype of the CTF3 RF deflector.

6. List of the Presentations

1. R&D for CLIC technology feasibility study J.P. Delahaye
2. CTF3, status of INFN collaboration A.Ghigo
3. Overview about the JRA2: PHIN A.Ghigo
4. Overview of the present status of the SRF gun design and construction J.Teichert
5. The Eindhoven High-brightness Electron Source Programme
6. Electron acceleration in the Bubble regime: analytical theory and numerical simulations S. Gordienko
7. The laser based electron beam approach: review and perspectives V. Malka
8. An overview of CLIC accelerating and transfer structure development A. Grudiev
9. Development of a planar accelerating structure H. Henke
10. A short pulse two-beam accelerator with energy recuperation H. Henke
11. Status of the Linear Collider Alignment & Survey project A.Mitra
12. Design of an RF photo-injector in the framework of the JRA2 PHIN R.Roux
13. Stabilization of Accelerator Magnets to the Sub-nm Level R.Assman
14. Stabilization studies from LAPP/ESIA A. Jeremie
15. RF Deflectors for Combiner and Damping Rings F.Marcellini

References: included in the text.