GRAPHENE FLAGSHIP

WP HF ELECTRONICS

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Pourquoi le Graphene?

Graphene and related 2D materials have been recognized from the very beginning as promising candidates for future high frequency electronics because graphene shows an extraordinarily high carrier mobility and scaling of 2D materials should be possible beyond the limits of conventional 3D semiconductors.

Therefore, graphene should be the perfect material for bringing HF-electronics beyond the limits of current technology.

However, it is still unclear if graphene can really fulfil these expectations, although graphene has already demonstrated cut-off frequencies of 300 GHz at a gate length of 40 nm, which is comparable to the values obtained in the best III-V transistors and significantly larger than those in silicon transistors.

For real applications not only the cut-off frequency is an important figure of merit; the intrinsic voltage gain and f_{max}, the frequency where the power gain reaches unity are, even more important.

Objectives généraux

Within the work package *High Frequency Electronics*, the scientific and technological foundation for a success of graphene based devices in high frequency electronics will be laid.

The relevant process technology will be developed; key challenges like the relatively poor f_{max} will be tackled in order to enable applications not conceivable with existing technologies.

Applications to be addressed fall into the fields of :

- **data-communication,**
- **THz sensing and imaging**
- **flexible electronics.**

First systems to be realized in the flagship are transceiver units for data communication systems, analog-digital and digital-analog converters, THz-sources and THz- imagers.

Partenaires

Table 1-8: WP4 High frequency electronics

Work package number	4	**Start date or starting event:**	M1
Work package title	High frequency electronics		
Activity type	RTD		

- AMO (Allemagne): D. Neumaier, Coordinateur
- RWTH: Aachen Univ. (Allemagne)
- ALUD Alcatel-Lucent (Allemagne)
- DTU (Danmark)
- UAB (Spain)
- Chalmers Univ (Suède)
- AALTO Univ (Finlande)
- PMI: Politecnico de Milan (Italie)
- **IEMN Lille (France) : H. Happy**
- **LPA- ENS (France): B. Plaçais**
- **TRT-Thalès (France): P. Lagagneux**

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Partenaires Francais

- **LPA**
  - Groupe physique mésoscopique et optique (B. Plaçais, J.M. Berroir, C. Voisin, J. Tignon …)
  - Croissance graphène CVD/SiC : LPN (A. Ouerghi, A. Madouri)
  - Nanotechnology : ANR : IEMN (Happy),
  - Modelling, IEF (P. Dollfus)
  - EU : Aalto (P. Hakonen), KIT (R. Danneau)
- **IEMN**
  - Graphene on SiC and others 2D materials : close collaboration with LPN (A. OUERGHI Group)
  - Graphene growth by MBE on C-face of SiC : close collaboration with IEMN-EPIPHY (D. VIGNAUD Group)
  - Compact modelling - Non linear modeling – Modelling : Close collaboration with IMS (T. Zimmer Group), IEF (P. DOLLFUS Group).
- **TRT**
  - Groupe Technologie + Groupe de Physique (P. Legagneux, JP Mazelllier, O. Bezencenet, P. Bondavalli,…)
  - UMR spintronique CNRS/Thales pour la fab. dispositifs (P. Sénéor)
  - LPICM – Nanomade pour le graphène (C-S Cojocaru)
  - 3-5 Lab pour la stratégie dispositifs hyperfréquence (S. Delage, JC Jacquet)

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Objectifs à 30 mois

Parameter	Current state-of-the-art	Goal of WP4
Maximum Oscillation Frequency f_{max}	40 GHz	100 GHz
Contact resistance	200 Ωμm	100 Ωμm
Passivation	Does not exist yet	Successful demonstration
Maximum operation frequency of graphene based integrated circuit	10GHz	30 GHz
Complexity of graphene based integrated circuit (no. transistors)	2	10
Klein Tunnelling Switch	Does not exist yet	Successful demonstration
Integration of graphene based amplifier on graphene based opto-electronic device	Does not exist yet	Successful demonstration at GHz frequencies
Number of scientific publications	-	30
Number of invited talks	-	10
Number of patent applications	-	2
Number of PhD and Post-docs	-	15

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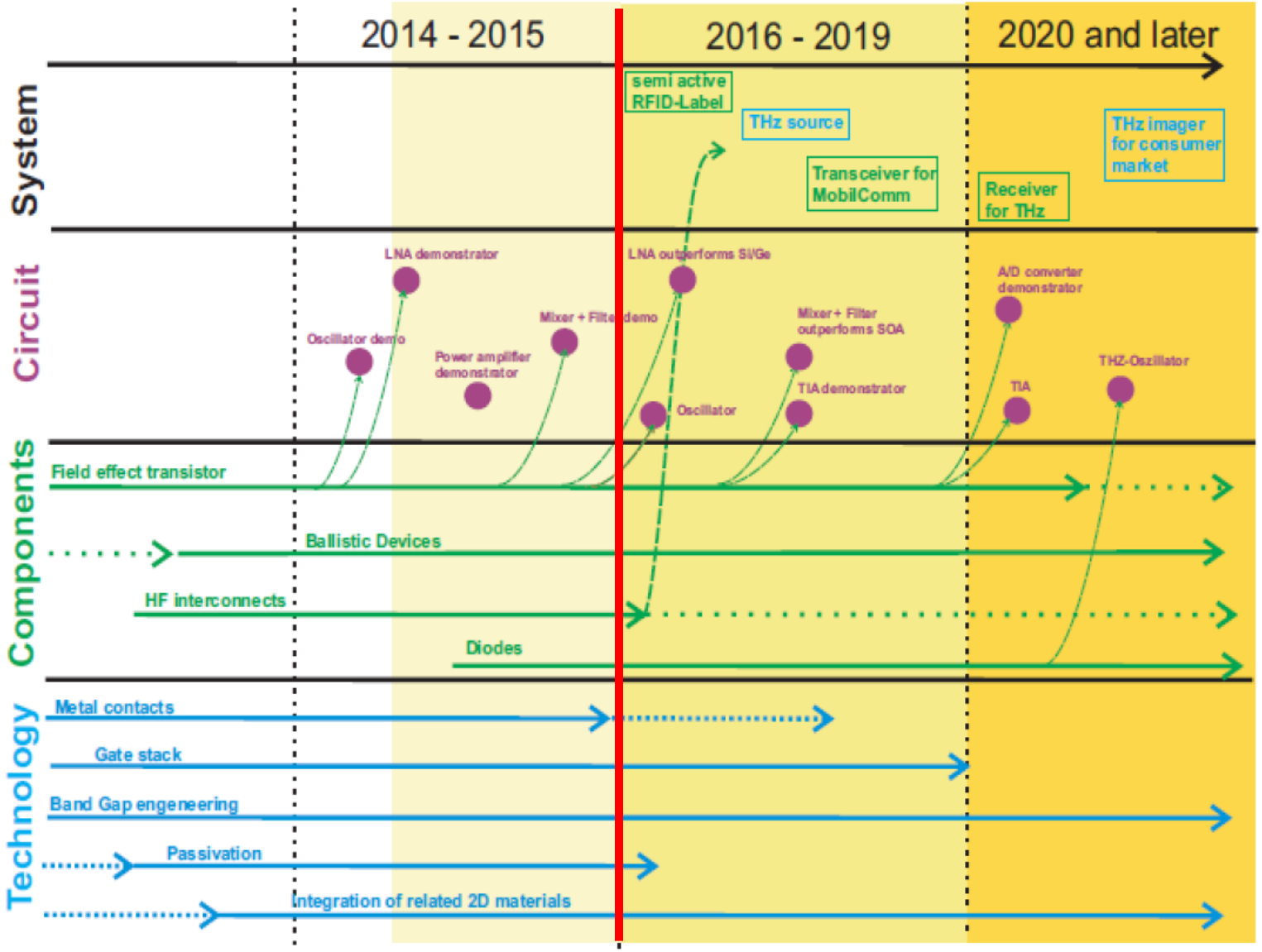
Roadmap



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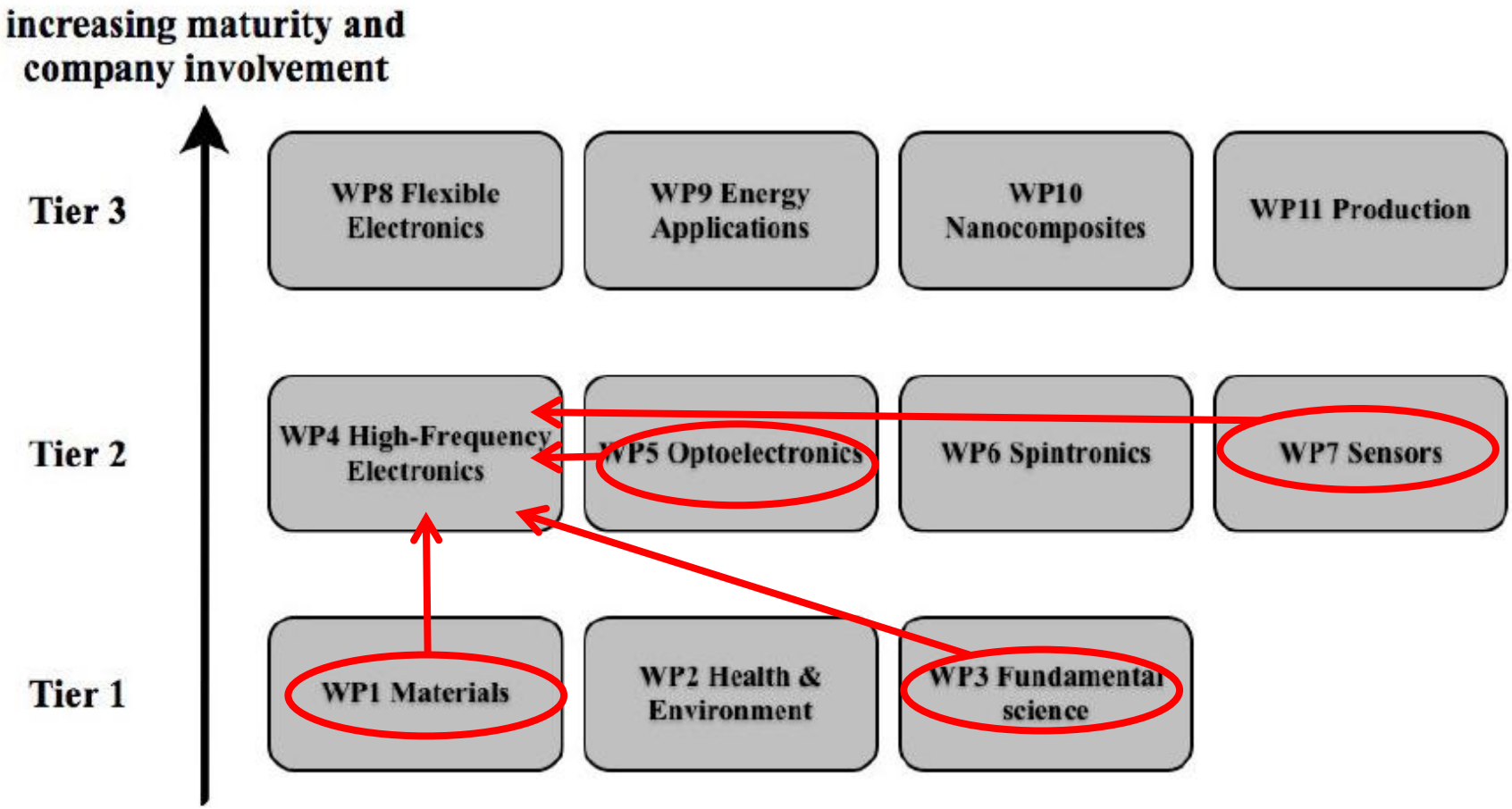
Collaborations avec les autres WPs

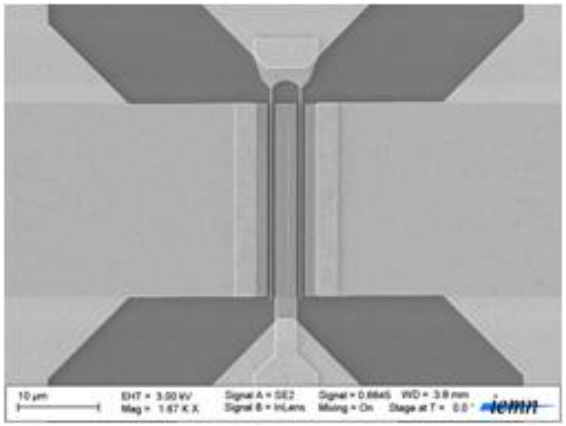


Tasks

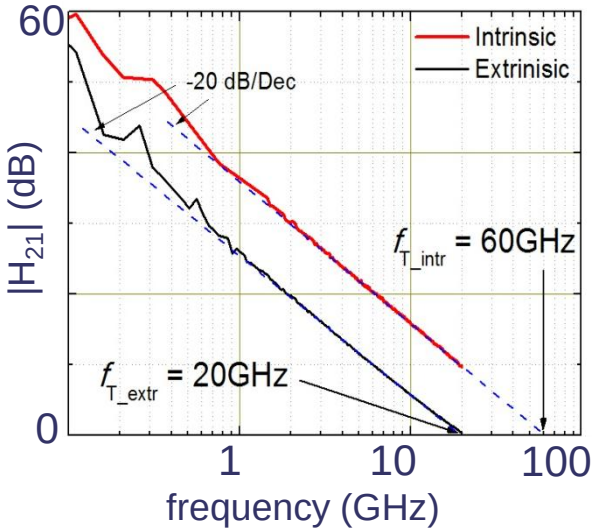
T4.1 - Development and optimization of process technology, realization of device components

Process technology for fabricating graphene-based devices will be developed and optimized towards the requirements of different device components.

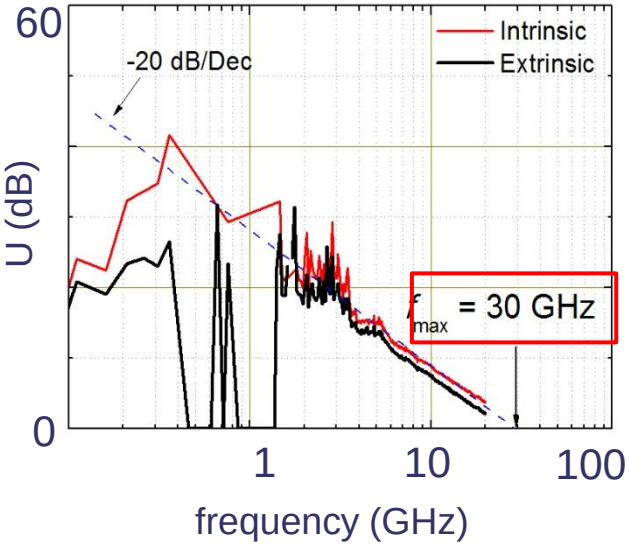
Interdisciplinary approach spanning from fundamental physics to electrical engineering (Close collaboration with CNRS-LPA)



Short circuit current gain



Mason's unilateral gain



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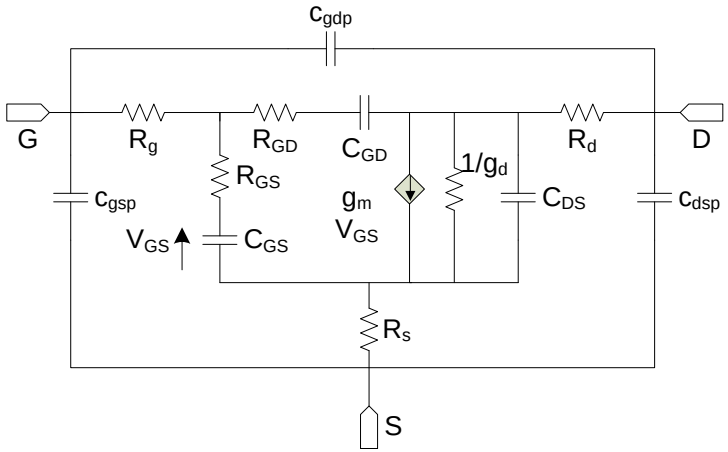
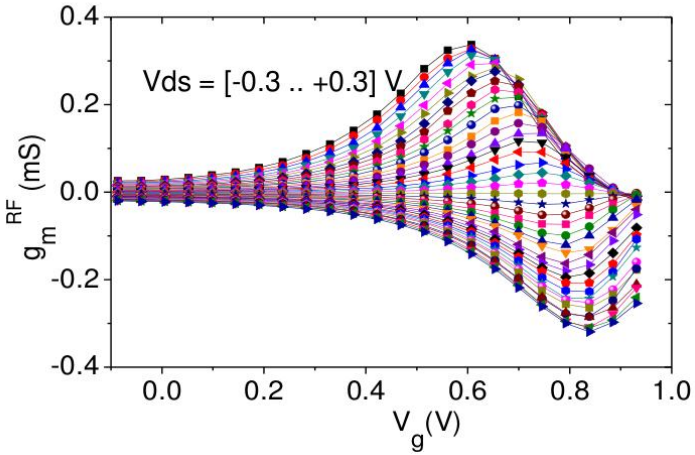
Tasks

T4.2: Circuit design, realization and testing

- Achieved generic circuits for system applications, for an operation frequency within the W-band, 75-110 GHz
- HF characterization through bias dependent S-parameters up to 110 GHz:
- Devices libraries
- Circuits design (LNA, Mixers) and fabrication





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Challenges technologiques

- **Dielectriques**
  - haute mobilité : $\mu > 10^4$ cm^2/V/s @ 10^{12} cm^{-2}
  - “Engineering” des phonons de surface (low kappa versus high kappa)
  - gate engineering

- **Devices**
  - Passivation
  - Resistance de contact
  - Large scale processing
  - Circuit designs et fabrication

Challenges scientifiques

- **Dispositifs à Fermions de Dirac balistiques (sur substrat)**
  - Dispositifs micro-onde à tunneling de Klein (“à la Vasalego”)
  - Propriétés dynamiques (S-parameters) et bruit (grenaille et thermique)
  - Mécanismes de diffusion résiduels
- **Interactions graphene-substrat**
  - Dynamique des DFs dans le champ proche du substrat (Surface Polar Phonons)
  - Vitesse de saturation et relaxation d’énergie